THESIS

THE SUBJECTIVE SENSE OF FAMILIARITY WITH MUSIC

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring 2020

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ABSTRACT

THE SUBJECTIVE SENSE OF FAMILIARITY WITH MUSIC

The process of familiarity—the mere sense or feeling of prior experience with something—remains poorly understood. Most theories assume that familiarity involves separable features held within memory traces, and some empirical evidence supports this notion. Familiarity appears to be at work in the metacognitive phenomenon known as déjà vu—the feeling of having experienced something before despite knowing that it is new—and its accompanying illusion of prediction. The present study examined the nature of musical features held within memory traces and their possible role in déjà entendu – the auditory version of déjà vu. Participants in Experiment 1 received studied songs in altered contexts at test. As in déjà vu research, the familiarity occurring in these altered auditory contexts related to reports of déjà entendu. In Experiment 2, repeated exposure to isolated musical features (rhythm or pitch) at study led to increased familiarity and déjà entendu reports with the full songs later. In Experiment 3, illusory feelings of prediction were shown to be associated with reports of déjà entendu. During déjà entendu, participants felt more able to predict the song's contour (Experiment 3a) and the sound location of the next note in the sequence (Experiment 3b). The full pattern of results suggest that separable features are a central component of the familiarity process with music, and that they play a role in déjà entendu. As shown in déjà vu research, both déjà entendu and feelings of familiarity are associated with illusory feelings of prediction.

ACKNOWLEDGEMENTS

Thank you to my advisor, Anne Cleary, for the encouragement, guidance, and feedback on this project.

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Chapter 1 - Introduction

Familiarity – the feeling of having encountered something before – has captured widespread interest in cognitive psychology since the field's inception. The feeling is well-illustrated in the following quote by Mandler (1991):

> "It is an experience all of us have had at some time or another: We meet somebody at a party, know them to be familiar but do not know who they are; we recognize a melody, but fail to remember its name or when or where we have heard it before; we read a line of a poem, know it, but do not know where we have read it before, much less the title or author of the poem" (Mandler, 1991, p. 207).

The experience of familiarity has been the subject of theoretical debates in recognition memory research for many decades (see Yonelinas, 2002, for a review). It has also been of interest to researchers of human decision-making processes and their underlying bases (Goldstein & Gigerenzer, 2002), as well as to researchers of metacognition (Schwartz & Cleary, 2016) insofar as the experience of familiarity might be viewed as a particular metacognitive state of awareness about one's memory. The present study is concerned with feelings of familiarity with music and how they compare to experiences of familiarity in other domains.

Feature-based Familiarity Detection

Many methods of studying the feeling of familiarity have been developed over the years (see Mandler, 2008, for a review). One of the most straightforward methods focuses on instances of cued retrieval failure, examining participants' ability to detect experimentally created familiarity with a cue or situation during retrieval failure (e.g., Cleary, 2004; Cleary, 2014; Cleary, Ryals, & Nomi, 2009; Ryals & Cleary, 2012; Cleary, Ryals, & Wagner, 2016). A growing body of research using this approach suggests a role of feature-matching – that is, an assessment of the degree of match between features stored in memory and features present in the cue – in the elicitation of the subjective experience of familiarity during retrieval failure.

The idea that feature-matching forms the basis of familiarity-detection is a long-held theoretical assumption captured in many formal models of recognition memory (see Clark & Gronlund, 1996, for a review of a class of such models known as global matching models and Cox & Shiffrin, 2017, for a dynamic variant). The idea is basically that upon being tested, all of the available cues are combined to create a memory probe. During recognition, the cues within the memory probe are used to access memory. Clark and Gronlund propose that it is not merely the original target memory being accessed by the probe, but rather the probe is activating multiple memories and information in parallel.

Recent research on familiarity and retrieval failure has used variants of a paradigm known as the recognition without identification (RWI) paradigm (Cleary & Greene, 2000). Basically, when participants are presented with the isolated features of a studied stimulus that they are unable to identify (or that corresponded to a target that cannot be retrieved), the isolated features themselves can elicit familiarity-based recognition. Although participants may not recollect the original stimulus, they may have feelings of familiarity with the isolated features, which is the phenomenon of *recognition without identification*. Due to these isolated features triggering feelings of familiarity, the paradigm itself can be used as a tool for probing the particular features that may be present within a memory trace. This notion underlies the approach taken in another paradigm that is based on the RWI paradigm, known as the recognition without cued recall (RWCR) paradigm (Cleary, 2004). In the RWCR paradigm, the notion of feature-matching is captured in cue resemblance to studied items. When a given test cue (e.g., POTCHBORK) fails to elicit recall of the studied target (e.g., PITCHFORK), familiarity-detection of the resemblance of the cue to something that was studied still occurs. Evidence supports the notion that this familiarity-detection is based on the feature-overlap between the cue and the studied target or targets (Ryals & Cleary, 2012). Using the RWI and RWCR paradigms, researchers have been able to identify several types of features that appear to be present, in a separable form, within a memory trace, ranging from visual to auditory features.

Visual Features and Feelings of Familiarity

The earliest studies of RWI involved isolating visual word features—specifically, letters—from potentially studied words on a recognition test. Participants would study a list of words (e.g., RAINDROP) and would later be given a recognition test containing word fragments, some of which corresponded to studied words (e.g., R_I__R_P) and some of which did not. Recognition without identification is the finding that, among word fragments that go unidentified, participants discriminate between those that came from studied words and those that did not (e.g., Cleary, 2002; Cleary & Greene, 2000, 2001; Peynircioğlu, 1990). The finding fits well within a feature-matching approach to familiarity detection, as it could be argued that the features in the cue (e.g., R_I__R_P) are matched with those in memory to produce a greater familiarity signal, on average, among fragments corresponding to unidentified studied words than to fragments corresponding to unidentified non-studied words.

Building on the earlier work with the RWI paradigm, Cleary (2004) used graphemic test cues (e.g., the cue *bashful* for the target word *bushel*) to find that, when cued recall failed, participants could still differentiate between test cues that graphemically resembled studied words compared to those that did not, as seen by familiarity ratings being significantly higher for the former than the latter. Ryals and Cleary (2012) expanded on the work done by Cleary (2004), examining how graphemic test cues and feature overlap affect RWCR. In their work, they proposed that in order to increase the familiarity signal, the features of the studied item must be present in both memory and the test cue. To support this hypothesis, concreteness was examined. For example, *forehead* is a concrete word while *aptitude* is an abstract word. While it is known that people tend to recall concrete words better than abstract words (e.g., Pavio, 1986; Pavio, 1991), in the example of a concrete word at study (e.g. *forehead*) and a corresponding graphemically similar nonword cue at test (e.g., *foneheed*), note that the concreteness of the study word is not reinstated in the nonword cue. Ryals and Cleary found that while concrete words were more likely to be recalled than abstract words, the magnitude of the RWCR effect did not differ between concrete and abstract words during recall failure. These findings support the feature-matching theory of RWCR and suggest that feature matching acts as the basis of recognition judgements during recall failure, and the features must be present within the cue.

Ryals and Cleary (2012) also provide support for the manipulation of feature overlap affecting familiarity-based recognition. By increasing the number of studied graphemic test cues that shared features (e.g., *pitchfork*, *patchwork*, *pocketbook*, and *pullcork*) with the cue (e.g., *potchbork*), there was a large difference in the RWCR effect. When a cue corresponded to a higher number of studied graphemic targets, participants exhibited higher cue familiarity ratings compared to when the cues only had moderate or no studied graphemically similar targets. In short, when the features embedded within a novel visual cue had originally been seen within recently viewed target items, participants were more likely to experience higher levels of familiarity with the cue, even when retrieval of any corresponding target words failed. These results suggest that a greater level of feature-overlap between a test cue and studied items in memory results in higher levels of familiarity with the cue itself at test during recall failure. Furthermore, these findings suggest that the cue's separable features can be extracted from the whole cue and matched with representations that exist within the memory trace, which produces feelings of familiarity.

Other types of visual features in memory traces have been examined with pictures. Cleary, Langley, and Seiler (2004) examined whether geons (Biederman, 1987) – basic geometric components that comprise images of everyday objects – might be presented within memory traces for recently viewed pictures and if isolated geometric components of pictures might produce familiarity-detection when image retrieval fails. In a pictorial analog to the earlier work on the RWI phenomenon with word fragments at test (e.g., R_I__R_P), Cleary et al. had participants study black and white line drawings of common, everyday objects such as a lamp or a coffee mug. At test, they presented participants with picture fragments. In one condition, the fragments contained junction points (enabling identification of some basic geometric shapes that were part of the original picture). In the other condition, the fragments had had the same number of pixels (so the same overall percentage of the original picture) but no intact junction points (making it difficult to identify any of the basic geometric components of the picture). An RWI effect was found, but only among fragments for which geon information was present in the fragments. When geons were not present in the fragments, participants could no longer discriminate based on familiarity when picture identification failed. These results suggest that geons – basic geometric shapes present in images of objects – are part of memory traces for studied pictures and can be separated for use in familiarity-detection with partial picture information later.

Auditory Features and Feelings of Familiarity

If it is a general principle of memory that memory traces exist as sets of features, then evidence for a role of feature-matching in familiarity-detection should not be limited to the visual modality. Indeed, research suggests that auditory features can also play a role in familiarity-detection during recall failure. In an auditory analog to the visual word fragment (e.g., R_I_ _R_P) study initially done by Peynircioğlu (1990), Cleary, Winfield, and Kostic (2007) isolated phonemes at test that were spliced from whole spoken word recordings. Similar to the findings of Peynircioğlu (1990), Cleary et al. (2007) found that participants gave higher familiarity ratings to unidentified phoneme fragments that came from words that had been spoken at study than to unidentified phoneme fragments that came from words that had not been spoken at study. These findings suggest that the features that contribute to familiarity can be auditory in nature, and phonemes constitute one type of separable auditory feature in memory traces for studied information.

Expanding this work to the musical realm, Kostic and Cleary (2009) created a musical equivalent of the work done by Cleary et al. (2007), splicing musical notes from digitally constructed songs to create auditory song fragments. As this method had succeeded in producing familiarity-based recognition with visual and auditory word fragments, the researchers expected to find analogous results with music fragments. Indeed, when participants were presented with the isolated song fragments that corresponded to unretrieved studied whole songs, they were more likely to experience higher levels of familiarity. This suggests that feature-based familiarity detection can be used to recognize musical pieces, and also that musical features, such as notes, are held within memory traces.

To further explore the specific types of features that may contribute to familiarity-detection with music, Kostic and Cleary (2009) isolated the two primary features thought to be involved in music cognition – rhythm and pitch (Krumhansl, 2000). To isolate rhythm at test, the exact rhythm from each original song clip was tapped out on a wood block instrument in a single note at test. To isolate pitch, the original note order was maintained while the notes were made to adhere to an arbitrary, unstudied rhythm. Kostic and Cleary found that, among isolated rhythms or isolated pitch sequences in cases where the songs from which they came could not be identified, participants found the isolated features more familiar when they came from an unidentified studied song than when they came from an unidentified nonstudied song.

In more recent research on musical features in memory traces, McNeely-White and Cleary, (invited revision) examined whether isolated features at *study* affect familiarity-detection with whole song segments at test. That is, would embedding recently familiarized rhythms or pitch sequences into song segments lead them to feel more familiar to participants? This approach followed from an approach taken by Cleary and Greene (2000), in which they isolated words' letter features at encoding by presenting word fragments (e.g., R_I_ _R _P) and examining later recognition judgments given to test words (e.g., RAINDROP) whose fragments went unidentified at study. Higher recognition ratings were given to whole words at test when their fragments were studied and unidentified than when their corresponding fragments were not studied. Similarly, McNeely-White and Cleary (invited revision) presented participants with isolated rhythms or isolated tonal sequences at study. These features were then embedded within unaltered song clips at test. When a test song had had some of its features, either rhythm or tonal sequences, presented in isolation at study, there were higher feelings of familiarity with the whole songs than when the isolated features had not been studied. This suggests not only that rhythmic and tonal information are separable features held within memory traces, but also that features are separated not just at test, but also at encoding, and can be recognized within otherwise experimentally novel stimuli.

Abstract Features and Feelings of Familiarity

Additionally, an RWCR effect can be shown when stimuli overlap semantically. Cleary (2004) demonstrated that when participants are presented with studied words (e.g., birch) that were semantically related to test cues (e.g., cedar), they were more likely to give higher familiarity ratings to semantically similar studied words than those that had not been studied. In a follow-up study, Cleary, Ryals, and Wagner (2016) were interested in determining whether the feature-matching approach could account for the

RWCR effect that was present in Cleary's (2004) study on semantic similarity. In their study, Cleary, et al. (2016) presented participants at study with semantic features (e.g., "a_tree," "has_bark") that mapped onto the test cue, varying the degree of feature overlap, such that the test cue "cedar" would have high semantic feature overlap with four studied words (birch, oak, pine, willow), whereas the medium semantic feature overlap condition would only overlap with two of the studied words (birch, oak). They found that when there was high semantic feature overlap with unretrieved studied words, participants were more likely to give higher familiarity ratings during recall failure compared to when there was medium overlap. These findings support those of Cleary (2004) while also suggesting that the feature-matching theory of recognition during recall failure supports semantic features being held within memory traces. Additionally, the degree of feature overlap also affects the level of familiarity that is triggered by the test cue, which is in congruence with the conclusions of Ryals and Cleary (2012).

The features can also be analogical in nature. In a variant of the RWCR paradigm, Kostic, Cleary, Severin, and Miller (2010) had participants study a list of pairs of words (e.g., bird-nest) that were part of a four-word analogy grouping (e.g., bird:nest::beaver dam). On a later recognition test, they presented pairs of words, half of which were the analogical mappings to a pair that had been studied (e.g., beaver:dam). In the absence of recall of the target word pair (e.g., bird-nest), participants could detect increased familiarity among pairs that corresponded analogically to studied pairs. In short, analogical relations were detected in the form of familiarity during recall failure. Kostic, Booth and Cleary (2015) found a similar pattern among passages at test that were designed to map analogically onto to sayings and aphorisms (e.g., "Do not put all of your eggs in one basket.”). Finally, in what might be considered another form of analogical mapping from study to test, Cleary et al. (2012) found that otherwise novel test scenes that mapped in their spatial configuration to studied scenes were found to be more familiar during recall failure of the studied scenes. In this case, the analogical mapping was spatial.

Familiarity as a Subjective Metacognitive State

While memory research has largely focused on familiarity as a process that can be simulated through formal modeling or manipulated experimentally (e.g., Yonelinas, 2002), more recent research efforts have approached familiarity from a metacognitive standpoint. From this standpoint, familiarity can be thought of as a subjective state of awareness about one’s own memory during an instance of retrieval failure, much like how a tip-of-the-tongue experience is a subjective state of awareness about one’s own memory during word retrieval failure (Schwartz & Cleary, 2016). For example, Mandler’s (1980) *butcher-on-the-bus* phenomenon is an example of familiarity-based recognition; it occurs when someone recognizes a person on a bus (that happens to be the neighborhood butcher), but only feels a sense of familiarity with the person, failing to recall contextual details on the fact that this person is familiar because he is the butcher. The individual is aware of the ongoing lapse in memory and is even experiencing a sense of recognition that this person is known, but cannot retrieve the details of the relationship. This sense of awareness about one’s own memory might be considered a metacognitive state worthy of investigation in its own right.

Déjà Vu

A specific example of metacognitive state of awareness about memory that has to do with familiarity is déjà vu. In déjà vu, a person has the feeling that the current scenario (usually a scene) is extremely familiar despite knowing that the familiarity is inappropriate because the situation is not one that has been experienced before. According to Cleary (2008), déjà vu may represent a form of RWI that occurs within everyday life as people interact with their environments. As shown by Brown (2003), there is a positive correlation between instances of déjà vu and the amount of travelling an individual has done. Thus, déjà vu may occur due to high feature overlap with prior and current experiences (Cleary, 2008), which might explain how a situation can be recognized as new, yet feel extremely familiar.

A specific similarity hypothesis of déjà vu is known as the Gestalt Familiarity Hypothesis (Brown, 2004). According to the Gestalt Familiarity Hypothesis, déjà vu occurs due to a similarity in the configuration of the elements between the old and new situations (Cleary et al., 2009). Support for this hypothesis can be seen in Cleary et al. (2009) in which participants were shown configurally similar scenes with the elements of the study scenes mapping onto the elements of the test scenes. During retrieval failure, participants gave significantly higher familiarity ratings when the test scene corresponded to a spatially similar unretrieved study scene during déjà vu. These findings suggest that high feature overlap of the spatial relations of scenes results in high feelings of familiarity, and this may lead to feelings of déjà vu.

In more recent research, Cleary et al. (2012) expanded upon the findings of Cleary et al. (2009) by using 3D scenes, fully immersing participants with a 3D headmounted display. As déjà vu is a phenomenon that occurs in daily life, unfolding as time progresses, using 3D scenes should be a more realistic modality to elicit the déjà vu experience. As in Cleary et al. (2009), Cleary et al. (2012) manipulated the spatial configuration of scenes to alter the amount of feature overlap between study and test scenes. This resulted in significantly higher familiarity ratings for test scenes that corresponded to spatially similar unretrieved study scenes, as well as a greater likelihood of reporting déjà vu experiences, supporting the findings of Cleary et al. (2009) and the Gestalt familiarity hypothesis that déjà vu is a result of spatial similarities, relying on high feature overlap between old and novel scenes.

Déjà Entendu

A similar subjective metacognitive state to déjà vu is déjà entendu. Déjà entendu is the feeling of having heard something before despite knowing that it is completely new (Brown, 2004). This subjective state of familiarity with sound may be similar to déjà vu. Its distinction may be primarily in being elicited by sounds instead of scenes. For example, someone might be driving in a car, listening to the radio, when a new song begins to play. The song may be highly familiar, causing the person to experience a feeling of having heard it previously despite knowing that this is not the case. The lyrics, instruments, and artist are completely novel. Then, the person may realize that the song feels familiar because it includes the same melody as a popular song from the person's youth. This experience, while not as common as déjà vu, is still prevalent (for a review on the occurrence of déjà experiences, see Neppe, 1983). However, the déjà entendu phenomenon has received little experimental examination. In 1962, Buck and Geers conducted a survey that was developed to assess instances of psychological phenomena that had not been previously studied, such as synesthesia, dream imagery, depersonalization, and déjà vu. In their survey, they made a distinction between visual and auditory déjà vu, but did not provide details on how this distinction was made, nor did they conduct experiments to assess the nature of the subtypes. Their survey was only conducted with the intent of correlating the experiences with one another.

It was not until 1983 that Neppe officially created subtypes of the déjà experience, as researchers were overlooking the unique nature of each experience. In his work, Neppe defined the commonly known term of déjà vu as any experience that elicits inappropriate feelings of familiarity. In addition, he defined the experiences of déjà senti (already felt, smelt), déjà rêvé (already dreamt), déjà lu (already read), and déjà entendu (already heard). Déjà entendu encompasses more than merely hearing something, according to Neppe, but rather involves the entire scenario. However, he does not go on to clarify what all of this entails and which aspects of the scenario prompt déjà entendu, and, aside from Brown's (2004) reiteration of Neppe's (1983) work, there has not been a follow up to these descriptions since.

Aside from survey research and the original classification of déjà entendu, research focusing on the neurology behind epilepsy has included the common side effect of déjà vu. In these studies, the researchers have briefly mentioned the experience of déjà entendu (e.g., Wild, 2005; Vlasov, Chervyakov, & Gnezditskii, 2013), but did not examine it through experimentation, only mentioning that it does exist, and some patients experience inappropriate feelings of familiarity with sounds.

While research has examined déjà entendu through surveys or in relation to epilepsy, it was not until recently that the mechanism behind déjà entendu was experimentally examined. In their 2019 study, McNeely-White and Cleary proposed that because déjà entendu is a subtype of the déjà vu experience, which is the feeling of having experienced something before despite knowing otherwise (Brown, 2004), and which has been extensively studied (e.g., Cleary, 2008; Cleary, Ryals, & Nomi, 2009; Cleary et al., 2012; Cleary & Claxton, 2018), perhaps the two phenomena share similar mechanisms. As previously discussed, déjà vu is a result of familiarity-based recognition elicited by spatially similar but otherwise novel scenes; therefore, McNeely-White and Cleary proposed that perhaps déjà entendu is due to a similar configuration of auditory features held within memory traces. To present auditory analogs to the spatially similar scenes used in déjà vu research, NPR's Piano Puzzlers were used (Adolphe, 2018). The Piano Puzzlers program involves the re-writing of original famous songs, such as children's tunes, pop-songs, or folk songs, in the style of a classical composer, such as Chopin, Mozart, or Bach, by composer Bruce Adolphe. The original song is embedded within the Piano Puzzler, with some of the original features still intact yet masked by the new genre. When creating the Piano Puzzler, Adolphe selects a familiar tune, such as "Take Me Out to the Ballgame" or "She'll be Coming Around the Mountain," and turns it into a Piano Puzzler by either incorporating the tune into an actual piano piece with replicated music (sometimes with necessary harmonic alterations) by a composer such as Brahms, Beethoven, or Stravinsky; another approach is to quote fragments or phrases by a composer and then fill out the music with paraphrases or stylistic imitation; finally, the last approach is to imitate the composer without actually quoting any of the composer's works (B. Adolphe, personal communication, September 18, 2018). McNeely-White and Cleary proposed that, because the possible mechanism underlying the déjà entendu experience may be the juxtaposition between old and new songs, the Piano Puzzlers program may be a strong candidate for examining this relationship. Each Piano Puzzler retains the original melody within a new context while masking it, creating a juxtaposition between old and new melodies.

To investigate whether Piano Puzzlers might elicit a sense of déjà entendu, McNeely-White and Cleary (2019) presented participants with study lists consisting of original, unaltered versions of the songs. During the test lists, participants heard Piano Puzzlers, half of which corresponded to original songs heard at study while half did not. Participants were asked if they were experiencing déjà entendu for the Piano Puzzler, and whether they found it familiar. Upon analyzing trials that participants failed to identify the Piano Puzzler, it was found that déjà entendu was associated with strong feelings of familiarity compared to instances of non-déjà entendu. Additionally, while there were no differences in the probability of experiencing déjà entendu between Piano Puzzlers that were studied as original songs and those that were not, it was found that, when examining familiarity ratings as a function of déjà entendu and study status, a significant RWI effect was found. Interestingly, though, this effect was only found during instances of déjà entendu. When a Piano Puzzler had been studied as an original, unaltered song, and prompted a sense of déjà entendu, participants were more likely to find it familiar than if the Piano Puzzler was not studied as an original, unaltered song. This suggests a link between music RWI and déjà entendu.

The results of McNeely-White and Cleary (2019) provide evidence for déjà entendu occurring due to the juxtaposition between old and new features, which can be examined through the use of NPR's Piano Puzzlers. However, the question remains on how exactly déjà entendu occurs, as the RWI effect was only present when factoring in familiarity ratings. Therefore, one focus of the current study will be on the effect of exposure to features on the probability of experiencing déjà entendu.

Familiarity and the Illusion of Prediction

Déjà vu and Illusory Feelings of Prediction

A growing body of research suggests that high familiarity intensity in situations of retrieval failure are related to illusory feelings of prediction regarding what is coming next. In 2018, Cleary and Claxton conducted a study on déjà vu and feelings of prediction. It has been suggested that memory's primary adaptive function is to apply previous experiences to current events in order to predict the future (Schacter, Addis, & Buckner, 2007). If déjà vu, a form of retrieval failure, is based on previous experiences and memories, then perhaps it still incorporates the function of prediction. In their study, Cleary and Claxton used the same paradigm as prior déjà vu studies (e.g., Cleary et al., 2012) but incorporated first-person navigation videos, asking participants whether they were experiencing déjà vu and how strong their feelings of prediction were for the next turn. When participants experienced déjà vu, they were more likely to give higher ratings for feelings of prediction during recall failure; however, their predictive ability was only at chance. These findings suggest that the memory phenomenon of déjà vu is related to the function of prediction, despite these feelings being illusory.

The Role of Familiarity in Illusory Feelings of Prediction

A possible explanation for the relationship between déjà vu and feelings of prediction may be that high feature overlap between study and test scenes leads higher feelings of familiarity. Cleary, McNeely-White, Huebert, and Claxton (2018) suggest that the déjà vu experience leads the experiencer to feel as if the current event is on the verge of complete retrieval, including the order of actions, which may result in illusory feelings of prediction. As shown by Cleary et al. (2009), déjà vu is more highly correlated with feelings of familiarity than non-déjà vu, providing support for the hypothesis that déjà vu occurs due to feelings of familiarity and feature overlap. In their study, Cleary et al. (2018) focused in the relationship between familiarity, feelings of prediction, and déjà vu. By using the same method used by Cleary and Claxton (2018), Cleary et al. (2018) used the first-person navigation videos, pausing the video before a critical turn to ask participants whether they were experiencing déjà vu, whether they were experiencing feelings of prediction, and to rate their feelings of familiarity with the scene. It was found that feelings of prediction were more likely to occur during déjà vu, replicating the findings of Cleary and Claxton (2018), while also revealing that déjà vu reports accompanied by feelings of prediction were more likely to receive even higher familiarity ratings than instances of déjà vu that were unaccompanied by feelings of prediction. These findings were replicated in a follow-up experiment in which familiarity was measured with a yes-no response, showing a higher likelihood of reporting a feeling of familiarity among instances in which déjà vu was accompanied by a feeling of prediction. Although the study was primarily examining the interrelationships between déjà vu, feelings of prediction, and feelings of familiarity, the findings provide evidence that high familiarity may be a strong driver of feelings of prediction during déjà vu, which may extend to feelings of prediction with high familiarity for musical pieces. In short, familiarity in general may contribute to illusions of prediction, and if so, it is possible to see an illusion of prediction accompanying familiarity with music, and the state of déjà entendu.

Déjà Entendu and Illusory Feelings of Prediction?

Prior work has shown a relationship between familiarity and feelings of prediction with visual stimuli (Cleary et al., 2018), but no research has been conducted on familiarity and illusory feelings of prediction with music. Within the realm of music cognition research, there have been studies examining actual musical prediction for which note will come next. Rohrmeier and Koelsch (2012) discuss the relationship between expectations and prediction in music cognition. Melodic and harmonic features rely on tonal and scalar rules, and incorporating violations of these rules in musical pieces can lead to surprises. As people process music, expectations of what will play next and when an event will occur affect the emotionality and aesthetics of the piece. However, the research on music cognition, expectations, and prediction primarily focuses on the psychophysics of sound perception, the influence of Western musical rules, and the origins of musical expectations (e.g., Pearce & Wiggins, 2005). There is currently a lack of research examining familiarity-based recognition during instances of retrieval failure for musical pieces. Based on prior work examining déjà vu and feelings of prediction (e.g., Cleary et al., 2018) and research examining familiarity and feature overlap with music (Kostic & Cleary, 2009), reports of déjà entendu may also be accompanied by illusory feelings of prediction. However, no research to date has examined déjà entendu, let alone its relation to illusory feelings of prediction.

Current Study

The present study was designed to examine familiarity with musical features and its potential relation to déjà entendu. Little research has been conducted on auditory features held within memory traces, aside from the work done by Cleary et al. (2007), Kostic and Cleary (2009), and McNeely-White and Cleary (invited revision), and only one experimental study has been conducted on the déjà entendu phenomenon (McNeely-White & Cleary, 2019), which has been shown to share similar mechanisms with déjà vu. Therefore, feelings of familiarity with musical pieces were examined in the current study in order to investigate the musical features held within memory traces and how feature overlap affects familiarity while also examining the nature of déjà entendu. Toward this end, Experiment 1 examined how a change of context and increased exposure frequency affect participants' subjective familiarity with musical pieces. As seen in the work done by Cleary et al. (2012), the retention of spatial features from old to novel scenes produces higher feelings of familiarity, and this can be thought of as a change of context, insofar as it is new yet old within the context of the experiment, creating a potential juxtaposition between feelings of oldness and newness. At least with déjà vu, researchers have argued that the juxtaposition of oldness and newness is a critical feature of the experience. Through expanding on the work done by McNeely-White and Cleary (2019), the context of the musical piece between study and test was manipulated by changing aspects of its rhythmic structure, genre, and tonal information while retaining others to create the juxtaposition of familiarity and novelty. These findings provide insight into whether instances of this juxtaposition lead to more reports of familiarity and/or déjà entendu than musical pieces that are merely novel. These findings will demonstrate how embedding multiple familiarized features into a novel song might affect familiarity while also relating to the work on déjà vu. If retaining the features while altering the context affects levels and familiarity and déjà vu reports, then this should also extend to the realm of music and perhaps déjà entendu reports.

Additionally, as seen by McNeely-White and Cleary (invited revision) and Ryals and Cleary (2012), increasing the exposure frequency of study items' features significantly increases participants' familiarity with feature-overlapping test cues. By manipulating the presentation of song features at study, with songs being presented either once, three times, or not at all, I hypothesized that participants will have even higher reports of déjà entendu for songs that correspond to contextually similar songs presented three times at study.

In Experiment 2, I examined the effects of increasing exposure frequency to the features present in the feature overlap on familiarity judgments given to the musical pieces at test. This was achieved by using isolated rhythms and tonal sequences at encoding that may or may not be repeated. This not only replicated the work done by McNeely-White and Cleary (invited revision) but also addressed whether déjà entendu occurs due to a similar mechanism of déjà vu by examining whether increased feature overlap leads to higher reports of déjà entendu. Based on prior work on feature overlap and déjà vu (Cleary et al., 2012), I hypothesized that repeated exposure at study to the features critical to the later feature overlap in the test pieces result in higher ratings of familiarity while also increasing the probability of déjà entendu reports. Additionally, I hypothesized that when isolated features are presented multiple times at study, this will further increase familiarity ratings and the probability of déjà entendu reports.

Given that prior work has shown a relationship between feature overlap and feelings of familiarity and déjà vu (Cleary et al., 2012; Cleary et al., 2018), and also a relationship between feelings of déjà vu and feelings of prediction, in Experiment 3 I examined the hypothesis that level of feature overlap between musical pieces at test and the encoding phase relates to feelings of prediction with music. The familiarization of musical features has been shown to affect participants' familiarity ratings of song fragments when the whole song containing the features has been presented at study (Kostic & Cleary, 2007). Additionally, research examining visual features and familiarity has demonstrated a relationship with feelings of prediction and familiarity strength, such that higher familiarity is associated with feelings of prediction (e.g., Cleary et al., 2018). In Experiment 3, I examined whether increasingly familiarized musical features are associated with increased feelings of prediction, and also whether reports of déjà entendu are associated with feelings of prediction. Two versions of this experiment were conducted: Experiment 3a examined the sense of prediction regarding contour - whether the next note should ascend or descend in pitch. Experiment 3b involved examining whether the sound will play out of the left or right earpiece after alternating sound output throughout the song.

Chapter 2 - Experiment 1 (Context Change with *Piano Puzzlers*)

Method

Participants

Participants consisted of 108 undergraduate students from Colorado State University. Three participants were excluded due to either computer errors or not finishing the experiment. A power analysis using G-Power (Erdfelder, Faul, & Buchner, 1996) indicated that 90 participants is sufficient to detect a medium effect size (d = .40), assuming an alpha of .05, power of .95, and a repeated-measures ANOVA. All participants received course credit for participating in this experiment.

Materials

Stimuli consisted of 60 Piano Puzzler segments and variants of their corresponding original songs (the songs upon which the Piano Puzzlers were based). Most of these variants of the songs were played on the piano, but some were orchestral or violin. The Piano Puzzler segments were clips of those created by Bruce Adolphe (2018) and found on the publicly accessible websites of NPR (https://www.npr.org/podcasts/381443927/performance-today-s-piano-puzzler) and Performance Today with Fred Child (https://www.yourclassical.org/programs/performance-today/topic/piano-puzzler). The original variants of these songs (e.g., “The Girl from Ipanema,” “Take Me Out to the Ballgame”) were taken from YouTube. Clips of these Piano Puzzlers were created used Adobe Audition 3.0 software, ranging in length between 12 to 23s. The average study song clip was 13s while the average test song clip was 17s.

Procedure

After providing consent, participants were randomly assigned into one of six counterbalanced versions of the experiment. The 60 song segments were divided into five study-test blocks. Each test list consisted of 12 Piano Puzzler songs, with four corresponding to songs presented at study once, four corresponding to songs presented at study three times, and four not corresponding to songs presented at study, resulting in 16 total presentations on the study list.

Participants either completed the experiment in an individual room with music being presented through speakers or in a group room with multiple computers, requiring each participant to wear headphones. Before beginning the experiment, the participants were presented with instructions (see Appendix A). After each song was presented at study, participants saw a text box pertaining to whether the participant could identify the song. Once the study list consisting of eight unique songs and 16 total presentations was completed, participants then completed the test list.

Participants were instructed that they would hear songs that may sound similar to those heard at study, and that they would be asked to indicate whether they were experiencing déjà entendu, which was defined as “The feeling of having heard something before despite knowing that it is completely new.” They were also told that some songs may seem more familiar than others, and that they would be asked to identify the song if possible (see Appendix A).

There were 12 Piano Puzzlers per block for the test list, with one-third corresponding to studied songs presented three times, one-third corresponding to studied songs presented once, and one-third not corresponding to studied songs. These test songs were randomly-ordered. After listening to each song, a dialog box appeared, asking participants to indicate if they were experiencing déjà entendu (y=yes, n=no). Another dialog box then asked participants to indicate how familiar the song seemed on a scale of 0-10 (0=not at all familiar, 10=highly familiar), with the instructions that familiar would mean the song is similar to one heard at study. A third dialog box then asked participants if they could name the song. A song was considered identified if the participant typed in the name, the lyrics, or the composer. To account for demand characteristics, the order of asking for the déjà entendu judgment and subjective familiarity rating were counterbalanced across conditions, therefore creating six versions of the experiment.

Results

Identification Rates

Without consideration of exposure frequency condition, participants identified an average of 12% (*SD* = .07) of songs at study. For songs that were presented only once, participants identified an average of 16% (*SD* = .13) of songs, which was significantly lower than the average identification rate of 20% for songs that were presented three times at study (*SD* = .12), $t(104) = -2.49$, *SE* = .02, $p = .014$.

Overall identification rates for songs at test were also quite low, with participants identifying only 4% (*SD* = .05) of Piano Puzzlers on average. A repeated-measures ANOVA revealed a significant effect of exposure frequency condition on identification rates, $F(2, 208) = 18.97$, *MSE* = .002, $p < .001$. Piano Puzzlers that corresponded to songs presented once at study (*M* = .05, *SD* = .07) were significantly more likely to be identified than Piano Puzzlers that did not correspond to songs presented at study (*M* =

.02, *SD* = .03), *t*(104) = 4.63, *SE* = .01, *p* < .001. When Piano Puzzlers corresponded to songs presented three times at study (*M* = .06, *SD* = .07), participants were also more likely to identify the test song than when the Piano Puzzler did not correspond to songs presented at study, *t*(104) = 5.34, *SE* = .01, *p* < .001. However, there was no difference in identification rates between Piano Puzzlers that corresponded to songs presented once or three times at study, *t*(104) = -1.60, *SE* = .01, *p* = .113. These identification rates are in line with prior research examining music recognition without identification (e.g., Kostic & Cleary, 2009; McNeely-White & Cleary, 2009), with participants demonstrating higher recollection for test songs containing familiarized features from study.

Probability of Experiencing Déjà Entendu

To assess whether the probability of experiencing déjà entendu differed between Piano Puzzlers that did and did not correspond to songs presented a study, a paired-samples *t*-test was conducted. Unlike the findings reported by McNeely-White and Cleary (2019), there was a significant difference, with Piano Puzzlers corresponding to studied original songs that were unidentified at study (*M* = .31, *SD* = .18) leading to a higher probability of reporting déjà entendu than Piano Puzzlers that did not correspond to studied songs (*M* = .29, *SD* = .19), *t*(104) = 2.02, *SE* = .01, *p* = .046, *d* = .12. This difference in findings may be due to the current experiment incorporating increased exposure frequency to the original features at study that were embedded into the Piano Puzzlers at test. To examine this possible explanation of exposure leading to increased déjà entendu reports, a repeated-measures ANOVA was conducted, which did not show a significant effect of exposure frequency, *F*(2, 208) = 1.86, *MSE* = .009, *p* = .159.

Paired-samples *t*-tests showed that Piano Puzzlers corresponding to songs presented once at study (M = .31, SD = .19) were not more likely to elicit déjà entendu compared to Piano Puzzlers that did not correspond to songs presented at study (M = .29, SD = .19), $t(104)$ = 1.33, SE = .01, p = .187, which is congruent with the findings of McNeely-White and Cleary. However, upon comparing Piano Puzzlers that corresponded to songs presented three times at study (M = .31, SD = .20) to Piano Puzzlers that did not correspond to songs presented at study, a marginally significant difference was found, $t(104)$ = 1.93, SE = .01, p = .056, d = -.13 suggesting that that increased familiarization of features had an effect on the probability of experiencing déjà entendu. There was no difference in the probability of reporting déjà entendu, though, between Piano Puzzlers that corresponded to songs presented once versus three times at study, $t(104)$ = -.60, SE = .01, p = .553.

While these results do not conclusively provide evidence for the origins of déjà entendu, this still does not rule out the possibility of déjà entendu occurring due to feature overlap between study and test stimuli. As previously discussed, the Piano Puzzler stimuli do not contain the exact features present in the original songs, as Adolphe (2018) incorporates only elements of the original in combination with the mimicked composer's style or works. Additionally, as discussed in McNeely-White and Cleary (2019), the RWI effect was dependent upon participants experiencing a sense of déjà entendu, thus enabling them to discriminate between studied and unstudied songs. The potential of this dependency being present in the current experiment is discussed below.

The Recognition without Identification Effect

As demonstrated in prior research examining musical features and recognition (e.g., Kostic & Cleary, 2009; McNeely-White & Cleary, 2019), test songs containing familiarized features from study are given higher familiarity ratings than test songs not containing familiarized features even when participants fail to identify the song. The current experiment replicated these findings, with participants giving higher familiarity ratings to Piano Puzzlers corresponding to songs presented at study (*M* = 2.53, *SD* = 1.53) compared to Piano Puzzlers not corresponding to songs presented at study (*M* = 2.40, *SD* = 1.62), *t*(104) = 2.12, *SE* = .06, *p* = .037, *d* = -.08. This suggests that, during retrieval failure, participants are able to discriminate between Piano Puzzlers that correspond to studied songs clips and Piano Puzzlers that do not.

Of interest to the current study, though, is whether increased exposure frequency to a song's features at study has an effect on the recognition without identification phenomenon. Towards this end, a repeated-measures ANOVA was conducted, revealing a marginally significant effect, *F*(2, 208) = 2.83, *MSE* = .28, *p* = .061, η_p^2 = .027. Participants provided higher familiarity ratings to Piano Puzzlers corresponding to songs presented three times at study (*M* = 2.57, *SD* = 1.59) compared to Piano Puzzlers not corresponding to songs presented at study, *t*(104) = 2.38, *SE* = .07, *p* = .019, *d* = -.11. However, familiarity ratings did not differ between Piano Puzzlers corresponding to songs presented once at study (*M* = 2.49, *SD* = 1.55) and those that did not correspond to songs presented at study, *t*(104) = 1.21, *SE* = .07, *p* = .229, nor was there a difference between familiarity ratings given to Piano Puzzlers corresponding to songs presented once versus three times at study, $t(104) = -1.17$, $SE = .07$, $p = .245$.

The Relationship between Familiarity and Déjà Entendu Reports

McNeely-White and Cleary (2019) only found an RWI effect among déjà entendu reports; RWI was not found among non-déjà entendu reports. To examine whether the same was true in the present study, participants' familiarity ratings were analyzed as a function of reported déjà entendu state. When participants experienced déjà entendu ($M = 5.31$, $SD = 1.58$), they provided significantly higher familiarity ratings compared to when they were not experiencing déjà entendu ($M = 1.27$, $SD = 1.27$), $t(103) = 25.37$, $SE = .16$, $p < .001$, $d = 2.75$ (note that one participant was lost from the analysis due to not experiencing déjà entendu).

Of interest to the current experiment is whether increasing exposure frequency subsequently increases feelings of familiarity and the probability of experiencing déjà entendu. As previously seen in prior work on déjà entendu (McNeely-White & Cleary, 2019), the presence of déjà entendu enables participants to discriminate between studied and nonstudied songs. To replicate these findings, a 2 x 3 Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) x Déjà Entendu State (Déjà entendu, Non-déjà entendu) repeated-measures ANOVA was conducted. There was no significant main effect of exposure frequency condition, $F(2, 184) = 1.97$, $MSE = .51$, $p = .142$ (see Figure 1). However, there was a significant main effect of déjà entendu such that participants were more likely to give higher familiarity ratings during déjà entendu states than non-déjà entendu states, $F(1, 92) = 632.51$, $MSE = 3.69$, $p < .001$, $\eta_p^2 = .87$.

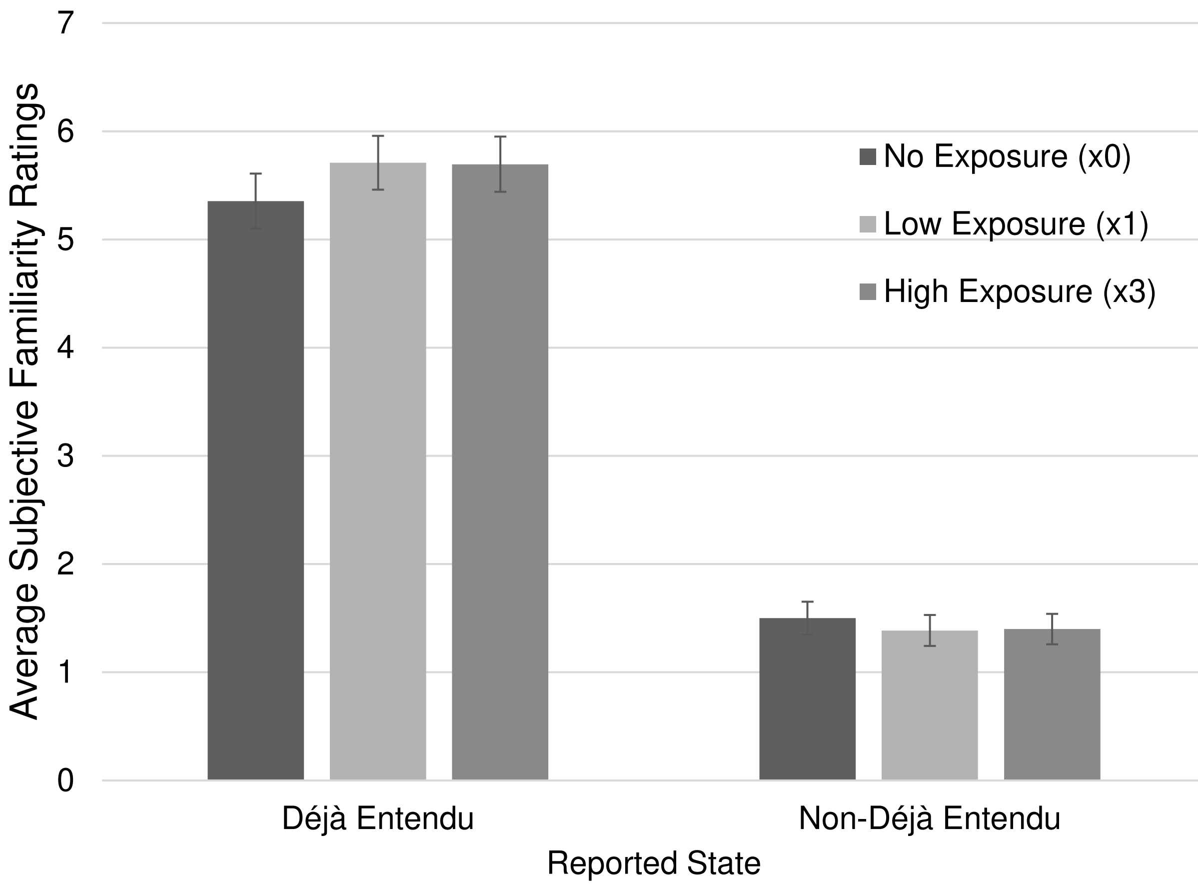

Figure 1. Familiarity ratings based on déjà entendu state and exposure frequency condition. During déjà entendu, participants are more likely to find Piano Puzzlers familiar overall, in addition to being able to discriminate between studied and nonstudied songs.

Additionally, there was a significant interaction, $F(2, 184) = 4.66$, $MSE = .57$, $p = .011$, $\eta_p^2 = .05$. When participants were experiencing déjà entendu, they were significantly more likely to provide higher familiarity ratings for the Piano Puzzler if it corresponded to a song presented once at study ($M = 5.58$, $SD = 1.63$) compared to if the Piano Puzzler did not correspond to a song presented at study ($M = 5.24$, $SD = 1.71$), $t(92) = 2.42$, $SE = .14$, $p = .017$, $d = -.20$. When exposure frequency during study was increased from only once to three separate instances, participants provided significantly higher familiarity ratings for Piano Puzzlers corresponding to songs studied three times ($M = 5.57$, $SD = 1.62$) compared to those that did not correspond to studied songs, $t(92) =$

2.31, *SE* = .14, *p* = .023, *d* = -.20. However, contrary to the hypothesized findings, there was no increase in familiarity ratings during instances of déjà entendu when comparing Piano Puzzlers that corresponded to songs presented once or three times at study, *t*(92) = .03, *SE* = .14, *p* = .977. Potential explanations are discussed below.

While participants did demonstrate the ability to discriminate between studied and unstudied Piano Puzzlers during instances of déjà entendu, as evident from their familiarity ratings, these patterns were not found during non-déjà entendu states. Compared to Piano Puzzlers that did not correspond to studied songs (*M* = 1.43, *SD* = 1.46), participants were not more likely to provide higher familiarity ratings compared to when the Piano Puzzler was studied once (*M* = 1.34, *SD* = 1.38), *t*(92) = 1.39, *SE* = .06, *p* = .167. Additionally, there was no difference in familiarity ratings during non-déjà entendu for Piano Puzzlers that corresponded to songs presented at study three times (*M* = 1.36, *SD* = 1.38) compared to those that did not correspond to songs presented at study, *t*(92) = 1.44, *SE* = .05, *p* = .154. The increase in familiarity ratings was also not found when comparing Piano Puzzlers that corresponded to songs presented at study once versus three times, *t*(92) = -.34, *SE* = .05, *p* = .736. This pattern replicates that which was found in McNeely-White and Cleary (2019) in that an RWI effect only emerged when a déjà entendu state was reported. Participants were only able to discriminate between studied and unstudied songs when experience déjà entendu.

Taken together, these findings provide additional evidence that, in order to discriminate between studied and unstudied Piano Puzzlers, participants must be experiencing déjà entendu. While the current experiment did not produce the anticipated effect of exposure frequency increasing familiarity ratings or the probability of experiencing déjà entendu, this may be due to the imprecise feature overlap between study and test songs. In consideration of the stimuli themselves, the experimental control typically used in recognition without identification studies (e.g., Kostic & Cleary, 2009; Cleary et al., 2012) was not present in the current experiment, as the Piano Puzzlers were created using an artistic methodology.

Chapter 3 - Experiment 2 (Specific Feature Familiarization)

One goal of the present study was to investigate whether feature overlap, as has been shown in déjà vu (e.g., Cleary et al., 2012), is related to reports of déjà entendu with music. As shown in the work done by McNeely-White and Cleary (invited revision) on isolated musical features, manipulating exposure frequency to isolated features at study results in increased familiarity-based recognition with novel songs that contain the studied rhythms or tonal sequences. While the Piano Puzzlers present a means of examining the effects of potential juxtaposition of familiarity and novelty presumed to underlie déjà entendu, unlike in studies of déjà vu, the specific types of feature overlap between Piano Puzzlers and their original songs varies and thus is not experimentally controlled. The purpose of Experiment 2 was to identify specific features that may contribute to familiarity with music and potentially with déjà entendu reports by isolating particular features at encoding. Toward this end, Experiment 2 examined whether manipulating exposure frequency to isolated rhythms or pitch sequences at study results in higher familiarity intensity ratings for unretrieved unaltered song clips, and whether the probability of déjà entendu reports increase at all when participants have studied isolated rhythms and tonal sequences and if so, whether this varies according to the degree of exposure frequency to those features at encoding.

If manipulating exposure frequency to features does in fact increase familiarity intensity ratings and/or the probability of reporting déjà entendu, then this would support the role of a global matching type of feature-matching process in feelings of familiarity with auditory stimuli such as music. Additionally, these findings would provide converging evidence for rhythm and pitch features being held within memory traces, contributing to our current understanding of how these features activate within the memory traces to produce feelings of familiarity. Finally, if increasing feature-overlap increases reports of déjà entendu, this would suggest that like déjà vu, déjà entendu may be the result of the amount of feature overlap between the current situation and an unretrieved situation in memory.

Method

Participants

Participants were 127 undergraduate students from Colorado State University who received credit toward an introductory course for participating. Due to either not finishing the experiment, computer errors, or in some cases a firm alarm, 12 participants were lost from data analyses, leaving a total of 115 participants. A power analysis using G-Power (Erdfelder, Faul, & Buchner, 1996) indicated that a sample of 114 participants is sufficient to detect a medium effect size (d = .40), assuming an alpha of .05, power of .95, and a repeated-measures ANOVA.

Materials

The stimuli consisted of 96 segments of well-known piano song clips from Kostic and Cleary (2009), such as a children's melody, a popular rock song, or a pop song, along with the isolated tone and rhythm versions of the piano segments. The piano song clips themselves were played in a single-note melody on the treble clef. The isolated rhythm segments were created by playing the rhythm for each song using only the middle C note on a woodblock instrument. This resulted in the sound of the song being "tapped out" on a wood block, with tonal information removed but the rhythm intact. The isolated tonal segments were created by attaching the original note sequence to a new rhythm for all song segments. This new rhythm consisted of a quarter note followed by two eight notes, which was repeated throughout the song clip while retaining the original tonal information. If a song's original rhythm had overlap with the new rhythm, adjustments were made to the new rhythm so that there would be no overlap. The study song clips ranged in length from 4 to 11s, with an average of 8.0s (*SD* = 2.0). The test song clips were also between 4 and 11s in length, with an average of 8.7s (*SD* = 1.7).

Procedure

After providing consent, participants were randomly assigned to one of sixteen counterbalanced versions of the experiment, in which a song clip at study was presented either as an isolated rhythm, isolated tonal sequence, or not at all. The 96 song segments were divided into eight study-test blocks. Each list contained a total of six unique isolated song features, with three being presented as isolated tonal sequences and three being presented as isolated rhythms. During the study list, three songs were repeated as a feature-type three times for a total of nine presentations while three songs were presented as a feature-type only once for a total of three presentations, resulting in 12 song clips being presented at study. For example, one version of the experiment repeated two isolated tonal features and one isolated rhythm three times while two isolated rhythms and one isolated tonal feature were presented once. This was counterbalanced across participants. The test list consisted of 12 unaltered song clips, with 3 corresponding to familiarized rhythms and three corresponding to familiarized tonal sequences.

Before beginning the experiment, participants read through several screens of instructions (see Appendix B). After each isolated song segment was presented, a text box appeared, asking the participant to make an attempt at identifying the song based solely on the rhythm or tonal features. Once the list of 12 isolated sequences was presented, participants then completed the test list.

In the test instructions, participants were told that they would hear full songs clips and that half of the song clips would have features presented in the study segment and half would not. They were also told to expect a question prompting them to indicate whether or not the test scene elicited a feeling of déjà entendu. They were told that "Déjà entendu is the feeling of having heard something before despite knowing that it is completely new." After reading through the instructions, participants could then press any key to begin the test list (see Appendix B).

Some of the unaltered piano clips on the test list corresponded to one of the six studied isolated feature sequences intermixed with six unaltered piano song segments for which no features were studied. Of the 12 unaltered song clips on the test list, half had their features familiarized at study. Of these, 3 had their rhythms familiarized at study and 3 had their tonal sequences familiarized at study. After listening to each unaltered song clip, the first dialog box appeared, asking participants to indicate if they were experiencing déjà entendu for the song (y=yes, n=no), with a reminder of its definition as: "The feeling of having heard something before despite knowing that it is completely new." The second dialog box then asked participants to indicate whether the song segment seemed familiar (y=yes/familiar, n=no/unfamiliar), with the instructions that familiar would mean the song segment likely corresponded to one of the isolated tonal sequences presented at study. If participants indicated that the unaltered song clip seemed familiar, they were then asked to rate how familiar the song felt on a scale of 0 (*not at all familiar*) to 10 (*strongly familiar*). Following this question, participants were then given the opportunity to identify the song. A song was considered identified if the participant typed in the name, the lyrics, or the composer.

Results

Identification Rates

See Table 1 for the proportions of songs identified at study and test. Overall, participants' identification of song features at study was low. When a song was presented as an isolated rhythm, there was no difference in identifying the feature if it was presented once or three times, $t(106) = -1.58$, $SE = .003$, $p = .117$. However, when a song was presented as an isolated tone, participants were significantly more likely to identify the feature if it was presented three times compared to if it was only presented once, $t(106) = 2.50$, $SE = .01$, $p = .014$. Additionally, as found in previous research (e.g., McNeely-White & Cleary, invited revision), identification rates differed between songs studied as isolated tonal sequences and isolated rhythms, with tonal sequences being more likely to be identified compared to rhythms when presented only once, $t(106) = 2.25$, $SE = 004$, $p = .026$, and also when presented three times, $t(106) = 2.85$, $SE = .01$, $p = .005$.

At test, participants were marginally less likely to identify unaltered song clips that contained familiarized features from study ($M = .19$, $SD = .11$) compared to unaltered song clips that did not contain familiarized features from study ($M = .20$, $SD = .12$), $t(106) = 1.78$, $SE = .01$, $p = .078$.

Table 1.
Proportions of songs identified from study and test.

	Study		Test	
	M	*SD*	*M*	*SD*
Overall	.008	.011	.20	.10
Rhythm x1	.006	.024	.20	.16
Rhythm x3	.012	.035	.20	.16
Tone x1	.016	.037	.19	.15
Tone x3	.029	.058	.20	.15

However, participants' identification rates for unaltered song clips that contained familiarized features did not differ as a function of the type of feature studied or the exposure frequency condition (*p*'s > .05).

The Recognition without Identification Effect

As expected based on prior research (e.g., Kostic & Cleary, 2009; McNeely-White & Cleary, invited revision), unaltered piano song clips containing familiarized musical features from study were more likely to be judged as familiar (M = .38, SD = .20) compared to unaltered piano song clips that did not contain any familiarized musical features from study (M = .30, SD = .20), $t(106) = 8.84$, SE = .01, $p < .001$, d = 0.40. When assessing subjective familiarity ratings provided to unaltered song clips that were judged as subjectively familiar during retrieval failure, participants gave higher subjective familiarity ratings to unaltered song clips corresponding to features that were presented at study but were unidentified (M = 6.0, SD = 1.4) compared to unaltered song clips that did not correspond to features presented at study (M = 5.7, SD = 1.7), $t(100) = 3.50$, SE = .10, p = .001 (note that six participants were lost from this analysis due to not judging either a studied or unstudied song as familiar). However, this analysis does not take into account the feature-type (rhythm or tone) presented at study or how frequently the feature-type occurred at study. To assess the influence of feature-type and frequency of exposure on familiarity judgments, two separate repeated-measures ANOVAs were conducted on unaltered song clips studied as isolated rhythms and isolated tonal sequences.

To replicate the findings of McNeely-White and Cleary (invited revision), who demonstrated that increasing exposure to isolated rhythms subsequently increases subjective familiarity with the whole song clips at test during retrieval failure, a repeated-measures ANOVA was conducted. As previously found, a significant effect was found, $F(2, 212) = 9.05$, $MSE = .01$, $p < .001$, $\eta_p^2 = .08$ (see Figure 2). When participants heard unaltered song clips that did not contain familiarized rhythms from study, they were less likely to judge the song clip as familiar than when they heard unaltered song clips that contained familiarized rhythms presented once at study, $t(106) = -4.37$, $SE = .01$, $p < .001$, $d = -0.27$. Compared to unaltered song clips that did not contain familiarized rhythms from study, participants were also more likely to judge unaltered song clips as familiar when they contained familiarized rhythms presented three times at study, $t(106) = 3.56$, $SE = .01$, $p = .001$, $d = 0.22$. However, unlike in McNeely-White and Cleary, a significant difference was not found between the probabilities of judging a unaltered song clip as familiar when it was studied once versus three times as an isolated rhythm, $t(106) = .30$, $SE = .02$, $p = .766$. Potential reasons for this are discussed below.

When examining subjective familiarity ratings given to unaltered song clips that were judged as subjectively familiar and corresponded to isolated rhythms, a repeated-measures ANOVA revealed a significant effect of exposure frequency, $F(1, 84) = 8.29$, $MSE = 6.9$, $p = .005$, $\eta_p^2 = .09$ (see Figure 3).

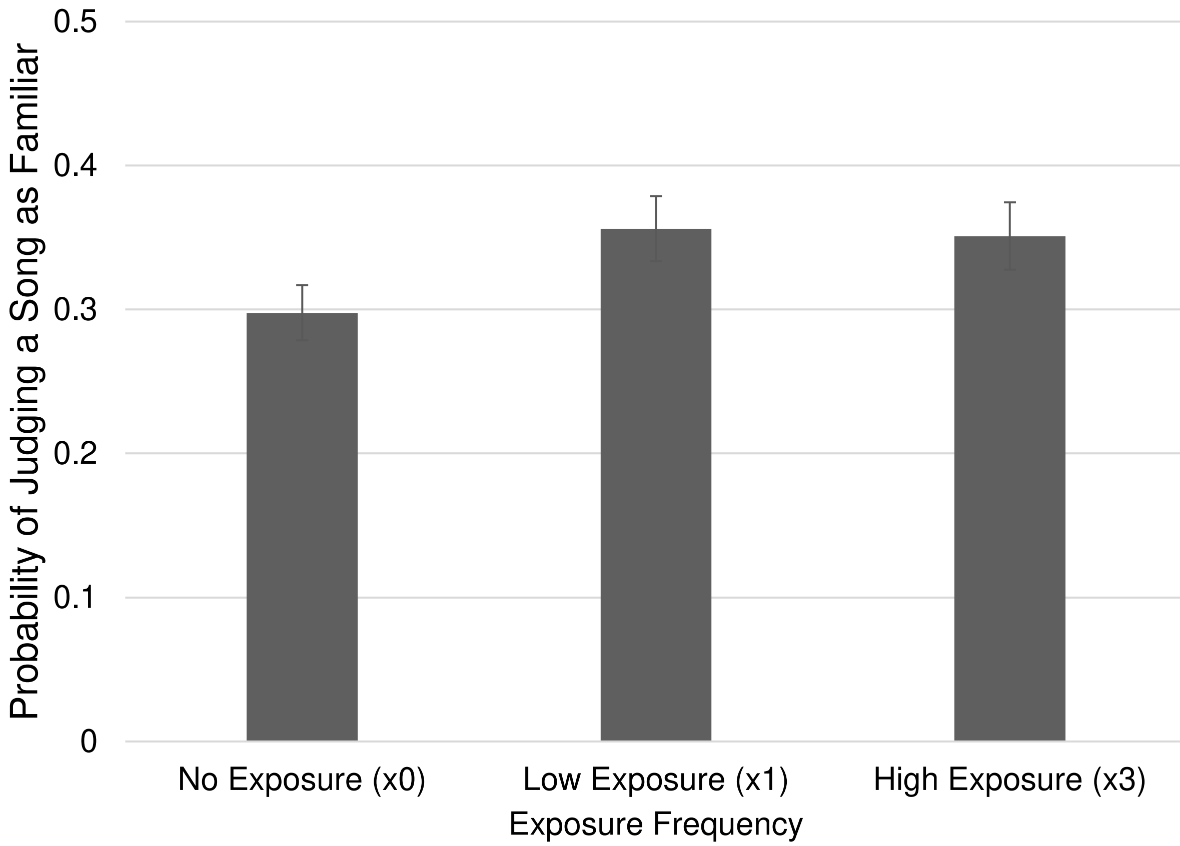

Figure 2. The probability of judging an unaltered song clip as familiar based on exposure frequency condition for songs that corresponded to familiarized rhythms. As exposure to the isolated rhythms increased, the probability of judging the song as familiar increased.

While there was no difference in the ratings provided to unaltered song clips that did not contain familiarized features (M = 5.8, SD = 1.6) compared to unaltered song clips that contained rhythms familiarized once at study and were unidentified (M = 5.8, SD = 1.8), $t(84) = -.41$, SE = .13, p = .687, there was a significant increase in the subjective familiarity ratings between songs that did not contain familiarized features and songs that contained rhythms familiarized three times at study and were unidentified (M = 6.2, SD = 1.7), $t(84) = -2.88$, SE = .14, p = .05, d = -0.25. There was also an increase in subjective familiarity ratings from whole song clips that contained rhythms familiarized once at study at unaltered song clips that contained rhythms familiarized three times at study, $t(84) = -2.56$, $SE = .14$, $p = .012$, $d = -0.21$.

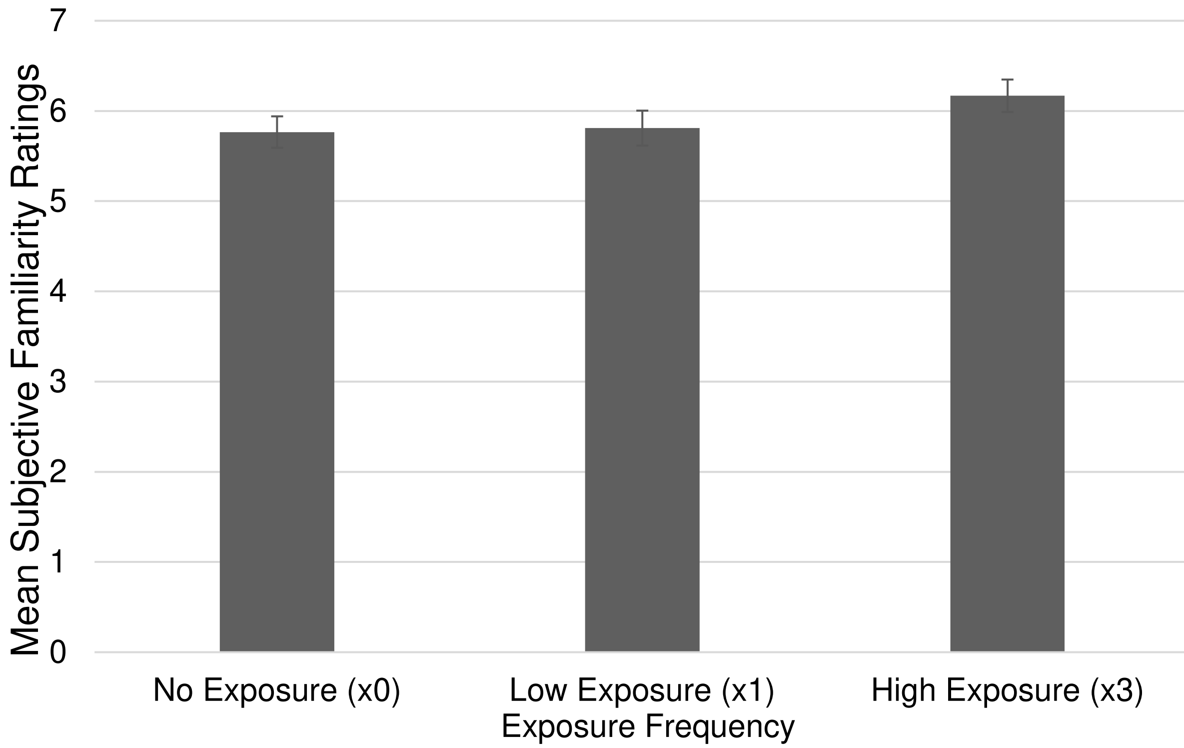

Figure 3. Participants' average subjective familiarity ratings given to unaltered song clips containing familiarized rhythms that were presented at study but unidentified. Participants provided higher ratings to songs if the rhythm was familiarized three times at study compared to only once or not at all.

For songs that contained isolated tonal features presented at study and were unidentified at study, a significant effect was found, $F(2, 212) = 36.24$, $MSE = .02$, $p < .001$, $\eta_p^2 = .23$ (see Figure 4). Participants were less likely to judge an unaltered song clip as subjectively familiar if it did not contain a familiarized tonal sequence compared to when the song clip did contain a familiarized tonal sequence presented once at study ($M = .38$, $SD = .23$), $t(106) = -4.80$, $SE = .02$, $p < .001$, $d = -0.38$. Additionally, compared to unaltered song clips that did not contain familiarized tonal sequences, participants were significantly more likely to judge unaltered song clips as subjectively familiar when the song contained a familiarized tonal sequence presented three times at study (*M* = .45, *SD* = .25), *t*(106) = 9.14, *SE* = .02, $p < .001$, *d* = 0.64. The difference between the probability of judging an unaltered song clip as subjectively familiar was significantly different for songs which contained a familiarized tonal sequence that was presented only once at study and songs which contained a familiarized tonal sequence that was presented three times at study, *t*(106) = -3.58, *SE* = .02, *p* = .001, *d* = -0.29. These findings suggest that, as exposure to the tonal feature-type increases, this subsequently increases participants' perceived familiarity with the unaltered song clip during retrieval failure.

Participants' subjective familiarity ratings for unaltered song clips containing familiarized tonal sequences that were unidentified at study were examined next. A repeated-measures ANOVA indicated that there was a significant effect of exposure frequency on subjective familiarity ratings, $F(2, 186) = 6.09$, *MSE* = 1.02, *p* = .003, $\eta_p^2 = .062$ (see Figure 5). During retrieval failure at study, participants' subjective familiarity ratings for unaltered song clips at test that corresponded to tonal sequences familiarized once at study (*M* = 5.96, *SD* = 1.57) were not significantly higher compared to unaltered song clips that did not contain any familiarized features from study (*M* = 5.76, *SD* = 1.57), *t*(93) = 1.47, *SE* = .14, *p* = .143. However, when exposure frequency at study was increased to three presentations, participants' subjective familiarity ratings (*M* = 6.27, *SD* = 1.49) were significantly higher for unaltered song clips compared to unaltered song clips that did not contain familiarized features from study, *t*(93) = 4.00, *SE* = .13, $p < .001$, *d* = 0.34. There was a marginally significant difference in subjective familiarity ratings for songs containing familiarized tonal sequences that were presented once compared to three times, $t(93) = -1.78$, $SE = .17$, $p = .078$, $d = -0.20$.

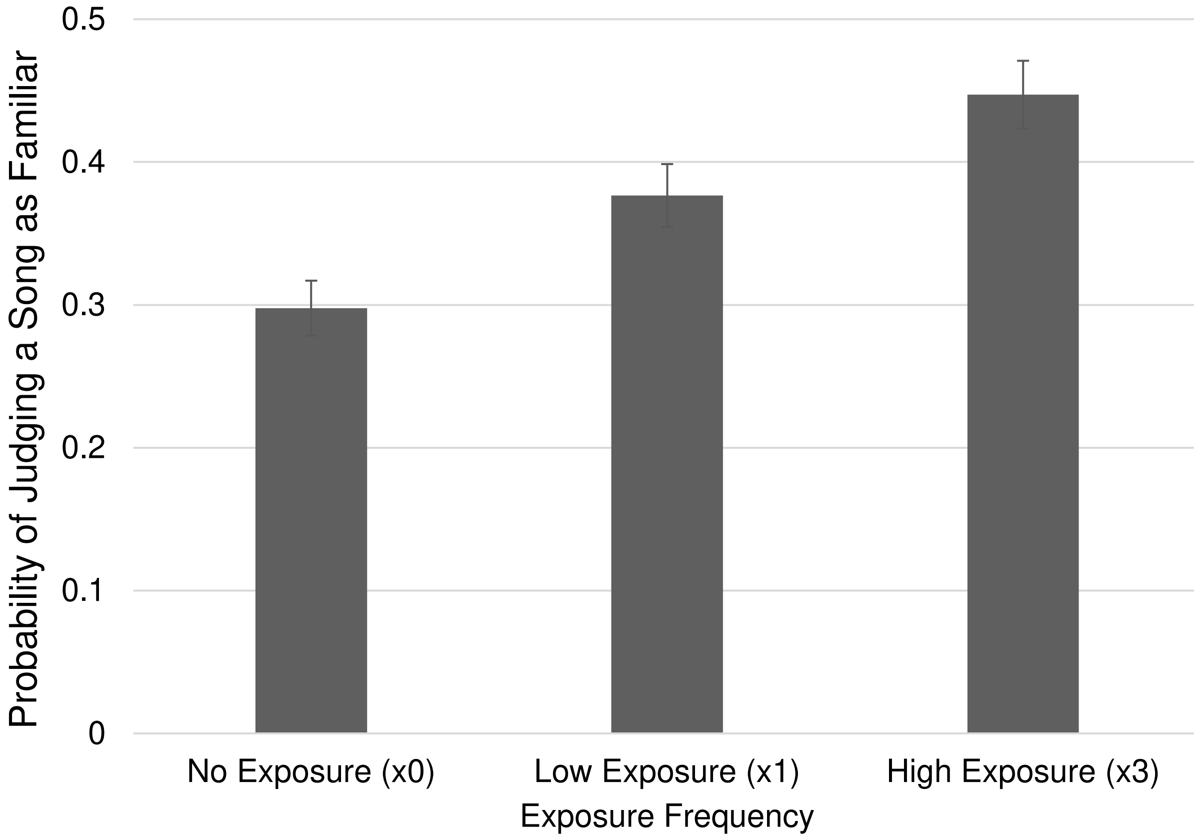

Figure 4. The probability of judging a song as subjectively familiar based on exposure condition for songs that corresponded to familiarized tonal sequences. As exposure to the isolated tonal sequences increased, the probability of judging the song as familiar increased.

To further assess the contributions of feature-type and exposure frequency on participants' perceived familiarity, a 2 x 2 Feature-Type (Rhythm, Tone) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted on songs that were unidentified at study, which showed a significant main effect of feature-type, $F(1, 106) = 17.97$, $MSE = .02$, $p < .001$, $\eta_p^2 = .15$ (see Figure 6).

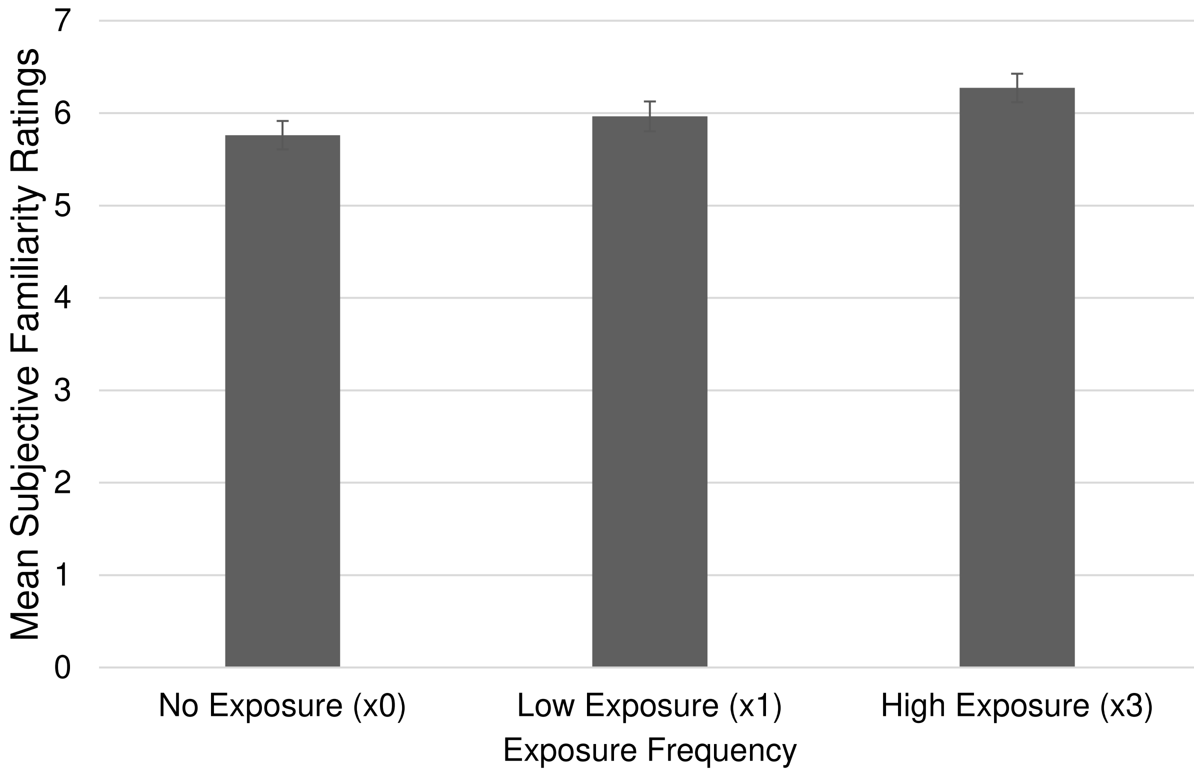

Figure 5. Participants' subjective familiarity ratings for unaltered song clips corresponding to tonal sequences presented at study. Participants provided higher ratings to unaltered song clips containing familiarized tonal sequences presented three times compared to those that did not contain any familiarized tonal sequence.

Participants were overall more likely to judge unaltered song clips as familiar when they contained familiarized tonal sequences from study compared to familiarized rhythms from study. Additionally, a significant main effect of exposure frequency was found, $F(1, 106) = 5.14$, $MSE = .02$, $p = .025$, $\eta_p^2 = .05$, such that a unaltered song clip was more likely to be judged as familiar if it contained a familiarized feature that was presented three times at study compared to only once; however, the presence of a significant interaction suggests that this effect is being carried by the tonal feature condition, $F(1, 106) = 10.89$, $MSE = .01$, $p = .001$, $\eta_p^2 = .09$.

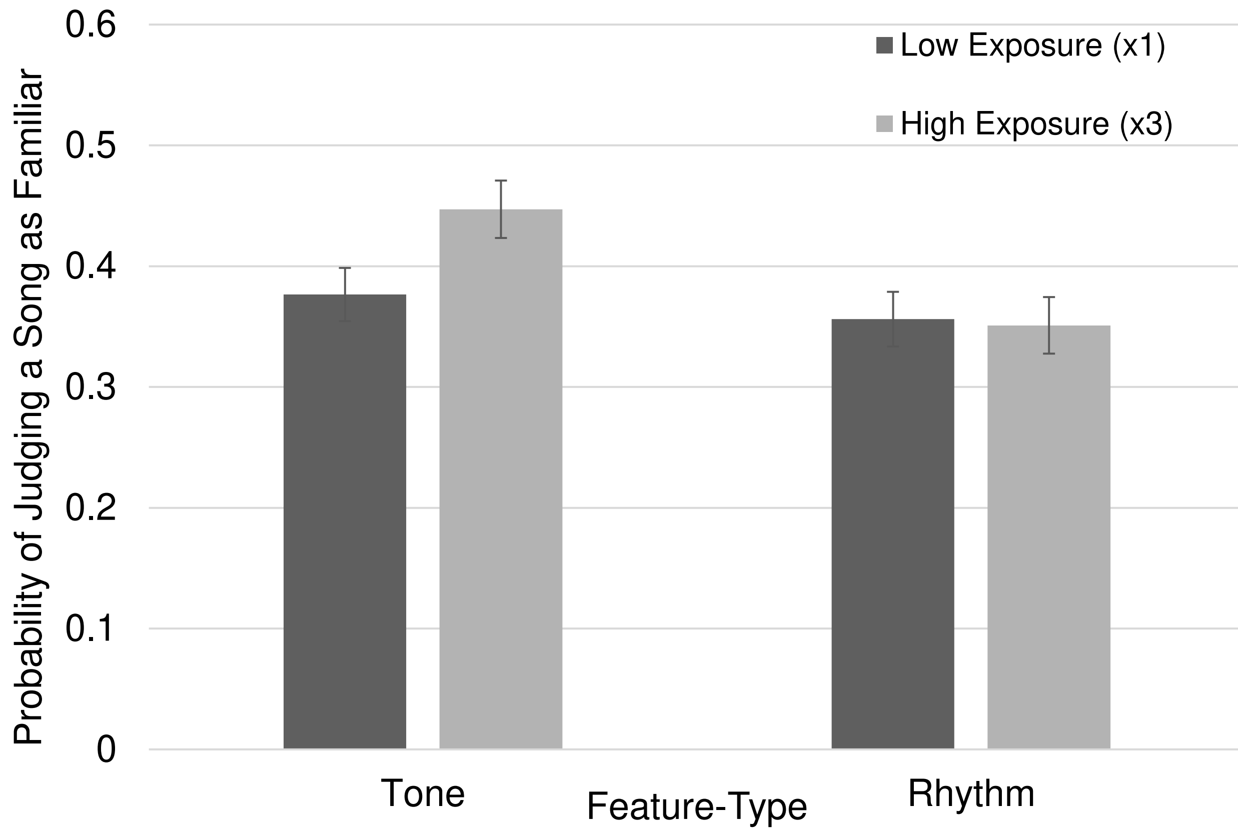

Figure 6. The probability of judging an unaltered song clip as familiar based on the feature studied and the exposure condition. Participants were significantly more likely to judge an unaltered song clip as familiar when it was studied as a feature three times, but this was only true for songs that contained familiarized tonal sequences. There was no difference in the probability of judging an unaltered song clip as familiar for songs that contained familiarized rhythms heard once versus three times at study.

The Déjà Entendu Phenomenon

Whereas Experiment 1 assessed the effects of exposure frequency on déjà entendu with varying degrees of feature overlap using Piano Puzzlers, the current experiment used precise feature overlap of isolated musical features. To first assess whether unaltered song clips containing isolated features from study resulted in increased feelings of déjà entendu, a paired-samples *t*-test was conducted. During retrieval failure at study, participants were more likely to experience déjà entendu for unaltered song clips at test that did contain familiarized features from study (M = .55, *SD* = .23) compared to unaltered song clips that did not contain familiarized features from study (*M* = .52, *SD* = .22), *t*(106) = 3.04, *SE* = .01, *p* = .003, *d* = 0.13. When factoring in the frequency of exposure at study, a repeated-measures ANOVA indicated a significant effect, *F*(2, 212) = 5.66, *MSE* = .01, *p* = .004, η_p^2 = .05. While there was no difference in the probability of experiencing déjà entendu for unaltered song clips that did not contain familiarized features compared to unaltered song clips that contained familiarized features presented once at study (*M* = .54, *SD* = .24), *t*(106) = -1.38, *SE* = .01, *p* = .170, participants were more likely to experience déjà entendu for unaltered song clips that contained features presented three times at study (*M* = .56, *SD* = .23) compared to unaltered song clips that did not contain familiarized features, *t*(106) = 4.16, *SE* = .01, *p* < .001, *d* = .18. There was only a marginal increase in the probability of experiencing déjà entendu when a unaltered song clip contained a familiarized feature presented once at study compared to three times, *t*(106) = -1.72, *SE* = .01, *p* = .089.

As discussed previously, the effects of exposure frequency when considering familiarity judgments emerged more distinctly when separately considering the type of familiarized feature. The importance of feature-type may also be a strong factor in assessing the effect of exposure frequency on the probability of experiencing déjà entendu. To assess this, two separate repeated-measures ANOVAs were conducted on the probability of experiencing déjà entendu given exposure condition for unaltered song clips containing familiarized tonal sequences and songs containing familiarized rhythms. First, when considering only unaltered song clips that contained familiarized tonal sequences from study, a significant effect was found, *F*(2, 212) = 7.61, *MSE* = .02,

$p < .001$, $\eta_p^2 = .07$. Compared to unaltered song clips that did not contain familiarized features from study, participants were marginally more likely to feel a sense of déjà entendu for unaltered song clips that contained familiarized tonal features presented once at study ($M = .55$, $SD = .26$), $t(106) = 1.75$, $SE = .02$, $p = .084$¸ $d = .12$. The probability of experiencing déjà entendu significantly increased for unaltered song clips that contained familiarized tonal features presented three times at study ($M = .59$, $SD = .24$) in comparison with unaltered song clips that did not contain familiarized features from study, $t(106) = 4.46$, $SE = .01$, $p < .001$, $d = .30$. The difference in the probabilities of experiencing déjà entendu for unaltered song clips that contained familiarized tonal sequences presented once compared to three times at study was marginally different, $t(106) = -1.94$, $SE = .02$, $p = .055$, $d = .16$.

The repeated-measures ANOVA on the effects of exposure frequency on the probability of experiencing déjà entendu for songs containing familiarized rhythms from study did not reveal a significant effect, $F(2, 212) = 1.29$, $MSE = .01$, $p = .277$, $\eta_p^2 = .01$. Unaltered song clips that contained familiarized rhythms presented once at study ($M = .52$, $SD = .26$) were no more likely to elicit déjà entendu than unaltered song clips that did not contain familiarized features from study, $t(106) = .20$, $SE = .01$, $p = .839$. When unaltered song clips contained familiarized rhythms presented three times at study ($M = .54$, $SD = .25$), participants were marginally more likely to experience déjà entendu compared to when unaltered song clips did not contain familiarized features, $t(106) = 1.80$, $SE = .01$, $p = .075$. There was no difference in the probability of experiencing déjà entendu when comparing unaltered song clips that contained familiarized rhythms presented once at study versus three times at study, $t(106) = -1.09$, $SE = .02$, $p = .280$.

In conjunction with the findings on the effect of exposure frequency on the probability of experiencing déjà entendu for unaltered song clips containing familiarized tonal sequences, these findings suggest that tonal information that is retained from study to test is a stronger influence on participants' senses of déjà entendu compared to rhythmic information. To support this inference, a 2 x 2 Feature-Type (Tone, Rhythm) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted, which revealed a significant main effect of feature-type, $F(1, 106) = 6.20$, $MSE = .02$, $p = .014$, $\eta_p^2 = .06$ (see Figure 7). Overall, participants were more likely to experience déjà entendu for unaltered song clips that contained familiarized tonal sequences compared to unaltered song clips that contained familiarized rhythms. There was also a marginally significant main effect of exposure frequency, $F(1, 106) = 3.77$, $MSE = .02$, $p = .055$, $\eta_p^2 = .03$, suggesting that as frequency of exposure to the isolated musical features increases, participants are more likely to experience déjà entendu. There was no interaction between the two factors, though, $F(1, 106) = .49$, $MSE = .01$, $p = .487$.

In McNeely-White and Cleary (2019), it was found that the RWI effect was dependent upon the déjà entendu phenomenon, such that participants were able to discriminate between studied and unstudied songs using their subjective sense of familiarity only when they were also experiencing déjà entendu. In their study, though, the test songs were *Piano Puzzlers*. To examine if a similar process occurs when using experimentally isolated and familiarized features, a 2 x 2 Study Status (Studied, Unstudied) x Déjà Entendu State (Déjà entendu, Non-déjà entendu) repeated-measures ANOVA was conducted.

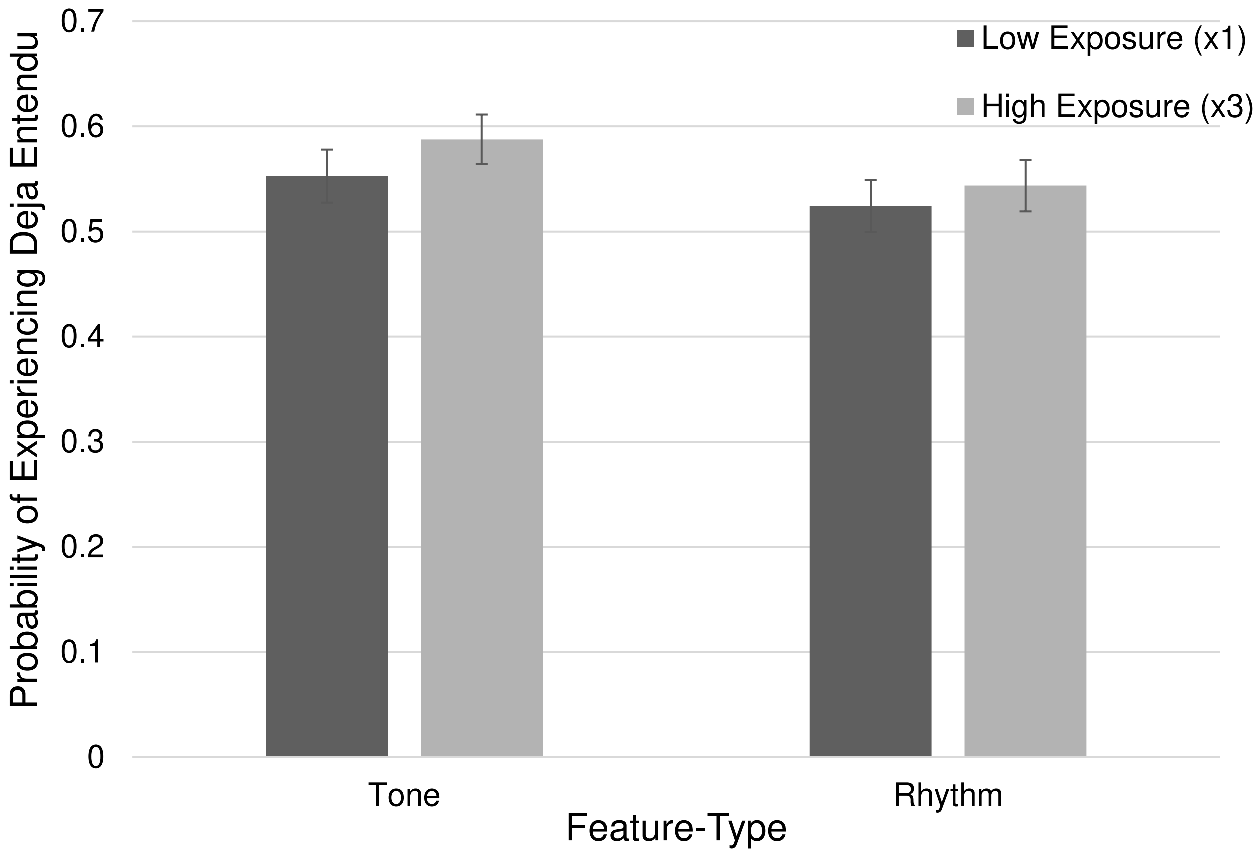

Figure 7. The probability of experiencing déjà entendu as a function of exposure condition and feature-type. Participants were overall more likely to experience déjà entendu for songs containing familiarized tonal sequences than familiarized rhythms. As exposure to the features increased at study, the probability of experiencing déjà entendu subsequently increased.

A significant main effect of study status was found, $F(1, 105) = 40.15$, $MSE = .01$, $p < .001$, $\eta_p^2 = .28$ (see Figure 8; note that one participant was lost from the analysis). When participants reported that they were experiencing déjà entendu, they were significantly more likely to judge an unaltered song clip as subjectively familiar if the unaltered song clip contained experimentally familiarized features from study that were unidentified ($M = .54$, $SD = .27$) compared to when the unaltered song clip did not contain experimentally familiarized features from study that were unidentified ($M = .45$, $SD = .30$), $t(105) = 6.56$, $SE = .01$, $p < .001$, $d = 0.33$.

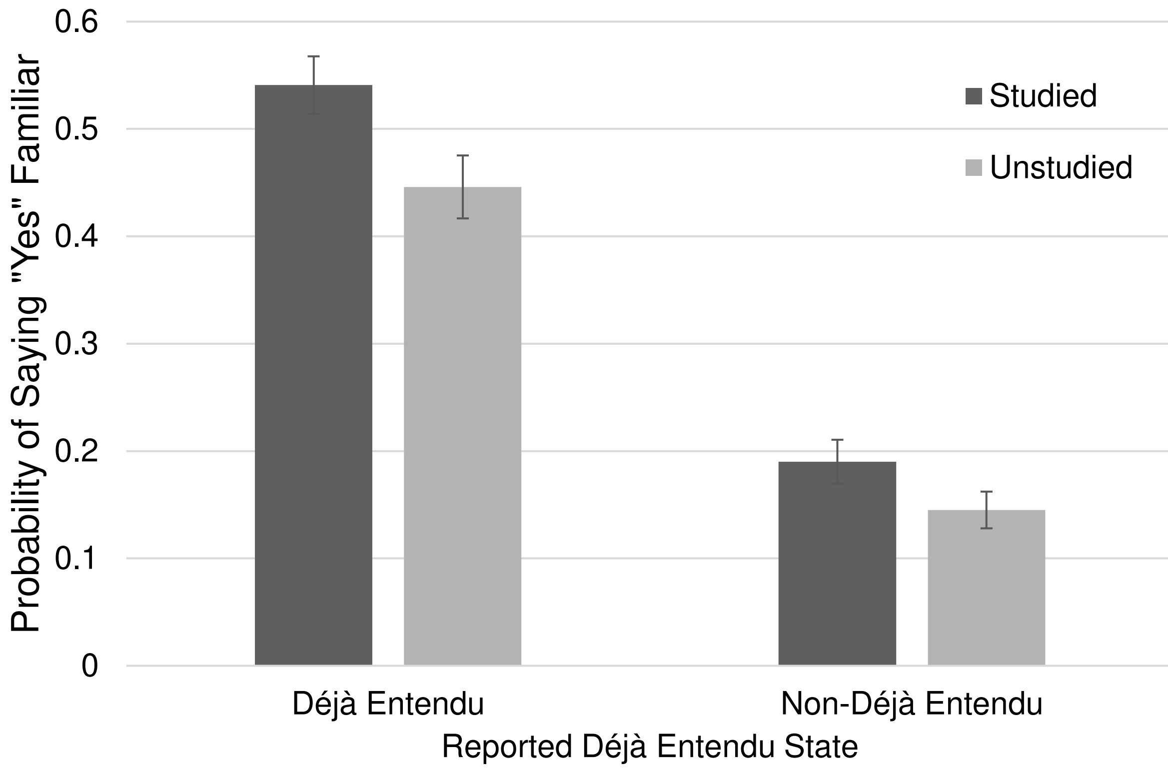

Figure 8. The probability of participants judging an unaltered song clip as subjectively familiar based on study status and reported déjà entendu state. Participants were more likely to judge an unaltered song clip as subjectively familiar if it corresponded to isolated features presented at study compared to if it did not. This ability to discriminate was more pronounced when participants reported that they were experiencing the subjective state of déjà entendu.

Additionally, even when participants reported that they were not experiencing déjà entendu, they were still more likely to judge an unaltered song clip as subjectively familiar if it contained experimentally familiarized features from study that were unidentified (M = .19, SD = .21), compared to when the unaltered song clip did not contain familiarized features (M = .15, SD = .21), $t(105)$ = 2.86, SE = .02, p = .005, d = 0.23. In consideration of the current findings in comparison with those of Experiment 1, it may be that the *Piano Puzzlers* stimuli are unique in how participants process them, as there are differences in how exposure affected the familiarity judgements between the two experiments.

The repeated-measures ANOVA also showed a significant main effect of reported déjà entendu state, $F(1, 105) = 11.25$, $MSE = .09$, $p < .001$, $\eta_p^2 = .54$, such that, when the unaltered song clips corresponded to familiarized features presented at study yet were unidentified, participants were more likely to judge the unaltered song clips as subjectively familiar if they were experiencing déjà entendu than if they were not experiencing déjà entendu, $t(105) = 11.23$, $SE = .03$, $p < .001$, $d = 1.44$. When participants were presented with unaltered song clips that did not correspond to features presented at study, they were also more likely to judge the unaltered song clips to be subjectively familiar if they were in a déjà entendu state compared to a non-déjà entendu state, $t(105) = 9.81$, $SE = .03$, $p < .001$, $d = 1.20$.

There was also a significant interaction found with the 2 x 2 Study Status (Studied, Unstudied) x Déjà Entendu State (Déjà entendu, Non-déjà entendu) repeated-measures ANOVA, $F(1, 105) = 5.85$, $MSE = .01$, $p = .017$, $\eta_p^2 = .05$. Although the RWI effect occurred among non-déjà entendu reports when using this set of stimuli, there was still an interaction that is consistent with the pattern obtained by McNeely-White and Cleary (2019), as the RWI effect was still larger among déjà entendu reports than non-déjà entendu reports. Overall, it appears that experiencing the metacognitive state of déjà entendu does indeed allow participants to further discriminate between items that were and were not previously encountered at study.

The Interaction of Exposure and Familiarity on Déjà Entendu

As previously seen in Experiment 1, familiarity plays a role in experiencing déjà entendu. To determine whether the precise familiarization of features influenced familiarity judgments which may have subsequently influenced the probability of experiencing déjà entendu, a paired-samples *t*-test was conducted on the probability of experiencing déjà entendu as a function of participants' subjective familiarity judgments. Participants were significantly more likely to experience déjà entendu when an unaltered song clip was judged as subjectively familiar (M = .77, SD = .27) compared to when an unaltered song clip was judged as subjectively unfamiliar (M = .41, SD = .24), $t(103)$ = 11.83, SE = .03, p < .001, d = 1.41 (see Figure 9; note that three participants were necessarily excluded from the analysis due to not judging songs as familiar during instances of déjà entendu).

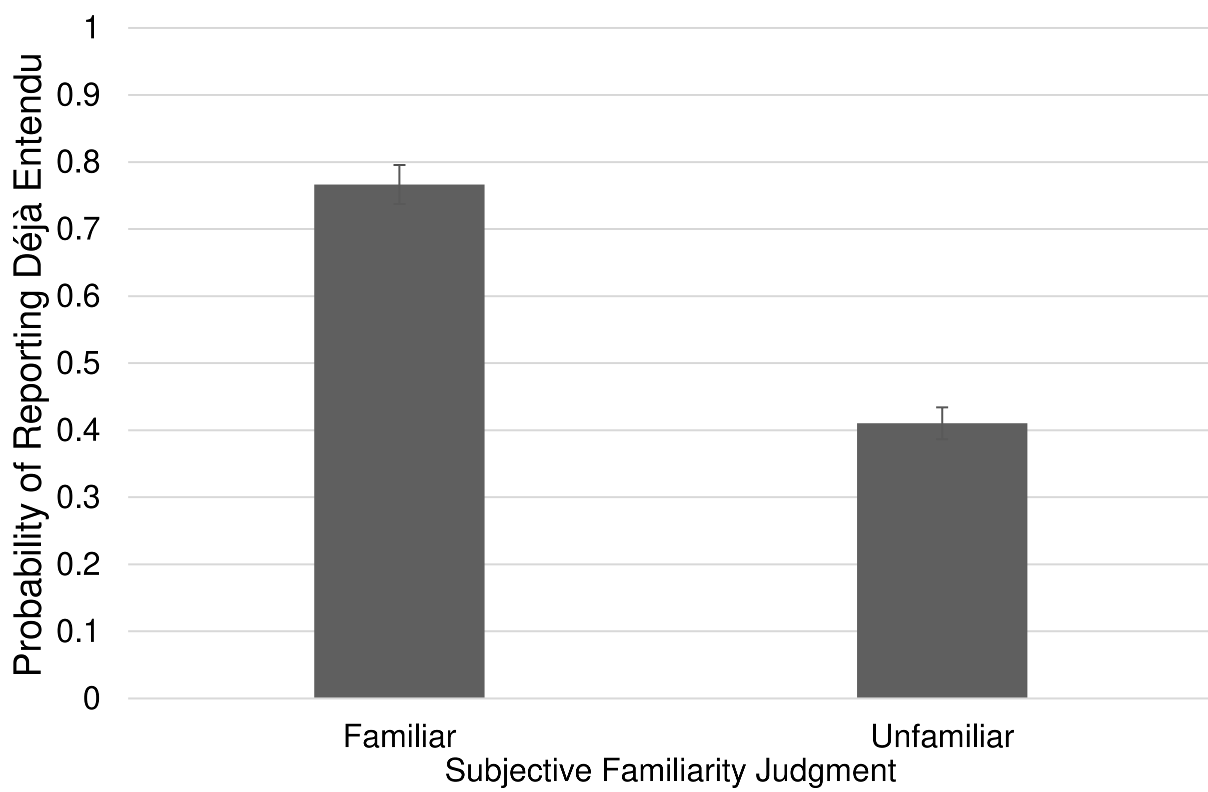

Figure 9. The probability of experiencing déjà entendu based on participants' subjective familiarity judgments. Participants were more likely to experience déjà entendu for songs that they judged as subjectively familiar.

To consider the relationship between familiarity judgments and exposure on the probability of experiencing déjà entendu, a 2 x 3 Familiarity Judgment (Familiar, Unfamiliar) x Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted, revealing a marginally significant effect of exposure condition, $F(2, 192) = 2.69$, $MSE = .02$, $p = .071$, $\eta_p^2 = .03$ (see Figure 10).

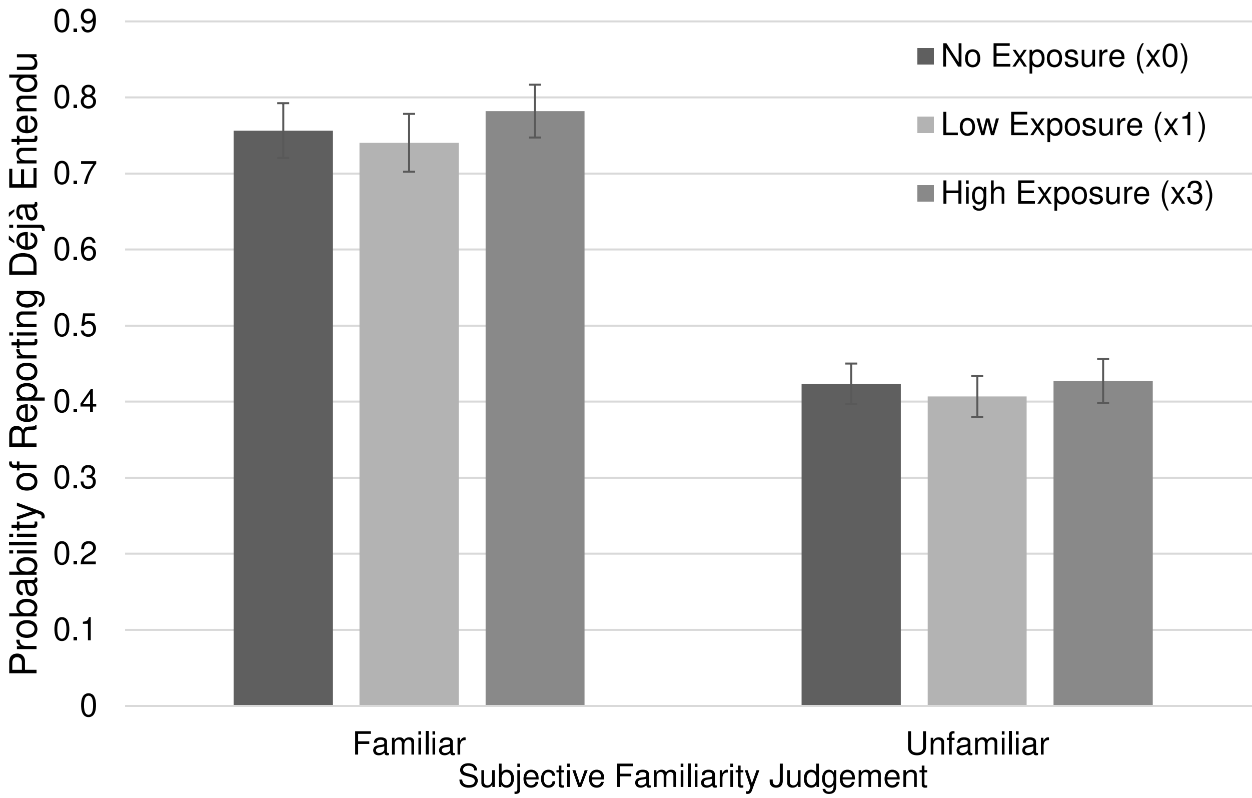

Figure 10. The probability of experiencing déjà entendu as a function of exposure frequency condition and participants' subjective familiarity judgments. Overall, participants were more likely to report having experienced déjà entendu when an unaltered song clip was judged as subjectively familiar. However, exposure to the unaltered song clips' features had little impact on the probability of experiencing déjà entendu.

While there was no increase in the probability of experiencing déjà entendu for unaltered song clips that were judged as familiar and contained features familiarized once at study ($M = .74$, $SD = .32$) compared to unaltered song clips that did not contain familiarized features ($M = .77$, $SD = .28$), $t(96) = 1.50$, $SE = .02$, $p = .138$, there was a marginal increase when compared to unaltered song clips that contained familiarized features presented three times at study ($M = .79$, $SD = .26$), $t(96) = -1.91$, $SE = .02$, $p =$

.06. There was no difference when comparing unaltered song clips that did not contain familiarized features and unaltered song clips that contained familiarized features presented three times at study, $t(96) = -1.12$, $SE = .02$, $p = .265$. Additionally, when comparing unaltered song clips that were judged as unfamiliar, there were no differences in the probabilities of reporting déjà entendu (p's > .05).

While there was only a marginally significant effect of exposure condition on the probability of reporting déjà entendu, a significant effect of familiarity judgment was found, $F(1, 96) = 129.21$, $MSE = .12$, $p < .001$, $\eta_p^2 = .57$, supporting the inference that familiarity is an influence in participants' déjà entendu experiences. There was no interaction between familiarity judgments and exposure condition, $F(2, 192) = .81$, $MSE = .02$, $p = .447$. As previously mentioned, when only considering the differences in judging an unaltered song clip as familiar based on its exposure condition, no significant difference was found when comparing unaltered song clips that did not contain familiarized features and unaltered song clips that contained familiarized features presented three times at study. One potential reason for these unanticipated results may be due to the experimental design. When participants were prompted to provide a familiarity judgment, they would subsequently be asked to rate the familiarity of the unaltered song clip only if they had judged the song clip as "Yes, familiar." To finish the experiment faster, participants may have responded "No, not familiar" even when an unaltered song clip was subjectively familiar so that they would not have to answer an additional question. Because of this, the data may not accurately reflect participants' true subjective familiarity judgments and subjective familiarity ratings.

Chapter 4 - Experiment 3 (Feelings of Prediction)

The purpose of Experiment 3 was to examine whether feelings of familiarity with music are related to feelings of prediction. As previously discussed, work on déjà vu is associated with increased feelings of familiarity and feelings of prediction (e.g., Cleary and Claxton, 2018; Cleary et al., 2018). While research in music cognition has examined actual predictive ability (e.g., Rohrmeier & Koelsch, 2012), there have not been any studies examining illusory feelings of prediction when there is high feature overlap in musical pieces. Therefore, Experiment 3 examined how feature overlap and feelings of familiarity influenced feelings of prediction for musical pieces, and whether déjà entendu played a role. This was studied in two similar experiments, the first using musical contour and the second using sound location.

Chapter 5 - Experiment 3a (Feelings of Prediction for Contour)

In Experiment 3a, the relationship between familiarity and feelings of prediction was investigated by requiring participants to predict the contour of a song. Musical contour is the rise and fall of notes, creating a dynamic flow of sound that progresses through time (Dowling & Harwood, 1986). Based on the research examining feelings of prediction during déjà vu (Cleary et al., 2018), Experiment 3a examined contour in relation to feelings of prediction with musical pieces. As contour can lead a song either up or down a scale, this can be thought of as an equivalent of a scene going either left or right. While there are Western scalar rules that restrict the exact note that will play next within a song (e.g., it must be within the scale to adhere to Western rules), there is an equal probability of a note increasing or decreasing in contour. Therefore, Experiment 3a presented participants with test song clips that mapped onto songs from study but paused before the end of the clip in order for participants to predict which direction the next note will lead the song. Additionally, Experiment 3a assessed the relationship between déjà entendu, familiarity, and feelings of prediction. I hypothesized that song clips with embedded familiarized features would result in higher feelings of familiarity and feelings of prediction, and that there would be a greater probability of reporting déjà entendu. However, I hypothesized that participants would have no predictive ability for the contour of the song.

Method

Participants

Participants consisted of 117 undergraduates from Colorado State University who received course credit as compensation. Due to computer errors or not finishing the experiment, five participants were excluded. A power analysis using G-Power (Erdfelder, Faul, & Buchner, 1996) software indicated that a sample size of 84 is sufficient to detect a medium effect size ($d = .40$), assuming an alpha of .05, power of .95, and a repeated-measures ANOVA.

Materials

From the song segments created by Kostic and Cleary (2009), 84 songs were altered using Adobe Audition 3.0 software to shorten the clips before the final note in order to enquire about feelings of prediction. The reason for not using all 120 song segments from Kostic and Cleary was that, after editing the songs to contain only one refrain, many were too short to use. The criterion of being longer than 2s was used as a determining factor of whether a song was included in the experiment.

Procedure

The procedure was identical to that of Experiment 2 with five alterations (see Appendix C for instructions). First, the 84 songs were divided into seven study-test blocks. Six unique isolated features were presented during each study segment, half of which were isolated tonal sequences and half of which were isolated rhythms. Of these six unique isolated features, three were presented only once and three were presented three separate instances during the study segment. During the test segment, participants were presented with 12 test song clips, half of which contained experimentally familiarized features from the study segment., A second alteration in Experiment 3a was that participants were presented with unaltered song clips at test that stopped just before the final note. Third, participants were asked if they felt as if they could predict whether the proceeding note would go up or down in pitch (y=yes, n=no). Fourth, an additional question concerning their actual prediction was included (u=up, d=down). Finally, participants were only asked to provide a familiarity judgment without the additional question of the familiarity rating.

Results

Identification Rates

See Table 2 for the proportions of songs identified at study and test. Overall, participants' identification of songs at study was low. When a song was presented as an isolated rhythm, participants were more likely to identify the song if it was presented three times compared to if it was presented once, $t(111) = 2.35$, $SE = .004$, $p = .021$. The same was also true for songs presented as isolated tonal sequences at study, with participants being more likely to identify a song if it was heard three times compared to if it was heard only once, $t(111) = 2.56$, $SE = .01$, $p = .012$. In examining differences in the proportions of songs based on feature-type, a significant difference was found for songs that were studied once as an isolated rhythm compared to an isolated tonal sequence, $t(111) = 2.91$, $SE = .04$, $p = .004$. When the exposure to features was increased to three instances, there was also a significant difference among identification rates based on feature-type, with isolated tonal sequences being identified at a higher rate than isolated rhythms, $t(111) = 3.04$, $SE = .01$, $p = .003$.

Table 2.
Proportions of songs identified from study and test.

	Study		Test	
	M	*SD*	*M*	*SD*
Overall	.008	.011	.18	.11
Rhythm x1	.003	.018	.16	.15
Rhythm x3	.012	.035	.16	.14
Tone x1	.016	.042	.18	.16
Tone x3	.031	.057	.17	.16

At test, participants were not more likely to identify unaltered song clips that contained familiarized features from study ($M = .17$, $SD = .12$) compared to unaltered song clips that did not contain familiarized features from study ($M = .18$, $SD = .12$), $t(111) = 1.63$, $SE = .01$, $p = .106$. When considering feature-type and exposure condition, participants' identification rates for unaltered song clips that contained familiarized features did not differ as a function of the type of feature studied or the exposure condition (p's > .05).

The Recognition Without Identification Effect

When prompted to judge whether or not an unaltered song clip felt familiar at test, participants were significantly more likely to judge the unaltered song clip as familiar if it contained familiarized features from study ($M = .39$, $SD = .20$) than if it did not ($M = .33$, $SD = .21$), $t(111) = 6.09$, $SE = .01$, $p < .001$, $d = 0.30$. When considering the type of feature presented at study, a repeated-measures ANOVA on songs corresponding to isolated tonal sequences showed a significant effect, $F(2, 222) = 12.42$, $MSE = .02$, $p < .001$, $\eta_p^2 = .10$ (see Figure 11). When participants heard an unaltered song clip containing a familiarized tonal sequence presented once at study but was unidentified ($M = .39$, $SD = .24$), they were more likely to judge the unaltered song clip as subjectively familiar compared to when the test song did not contain a familiarized feature from study (M = .33, SD = .21), $t(111) = 3.55$, SE = .01, p = .001, d = 0.23. When exposure frequency to the isolated tonal sequence at study was increased to three instances (M = .43, SD = .24), as opposed to none, participants were even more likely to judge the unaltered song clip as subjectively familiar, $t(111) = 4.80$, SE = .02, $p < .001$, d = 0.41. When comparing test songs that contained isolated tonal features presented once versus three times at study, a marginally significant difference was found, such that participants were more likely to find the unaltered test song clip familiar if it contained a familiarized tonal sequence presented three times at study, $t(111) = 1.89$, SE = .02, p = .061, d = 0.17.

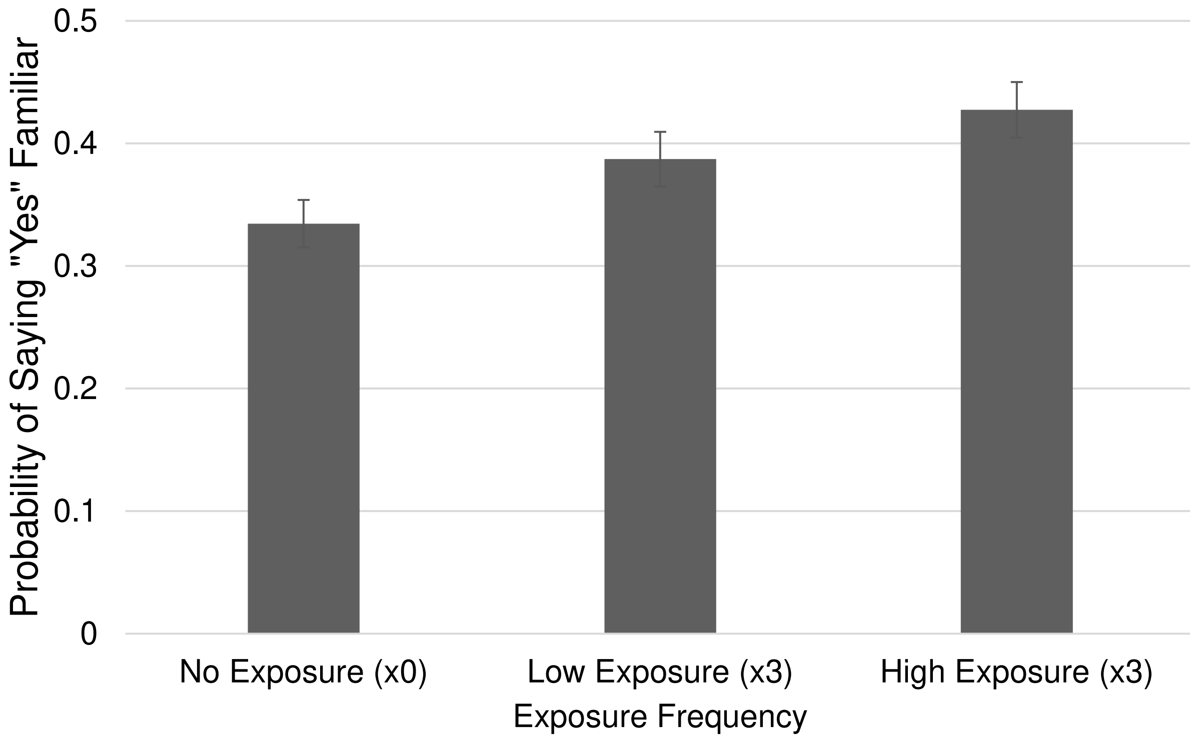

Figure 11. Probability of judging an unaltered song clip containing familiarized tonal sequences as familiar.

When considering participants' subjective familiarity judgments for unaltered song clips corresponding to familiarized isolated rhythms, a repeated-measures ANOVA revealed a significant effect, $F(2, 222) = 6.37$, $MSE = .013$, $p = .002$, $\eta_p^2 = .054$ (see Figure 12). Similar to when songs corresponded to familiarized tonal sequences, participants were more likely to judge a unaltered song clips as subjectively familiar if it contained a familiarized rhythm presented once at study ($M = .38$, $SD = .24$) compared to when it did not contain any familiarized features, $t(111) = 3.66$, $SE = .01$, $p < .001$, $d = 0.22$. When exposure frequency to the isolated rhythms was increased to three instances ($M = .38$, $SD = .22$), participants were more likely to judge the unaltered song clip as subjectively familiar compared to when it did not contain familiarized features, $t(111) = 3.10$, $SE = .01$, $p = .002$, $d = .20$. However, the added instances of exposure did not result in a significant difference in the probability of judging an unaltered song clip as familiar when it contained a familiarized rhythm presented once or three times at study, $t(111) = .40$, $SE = .02$, $p = .69$.

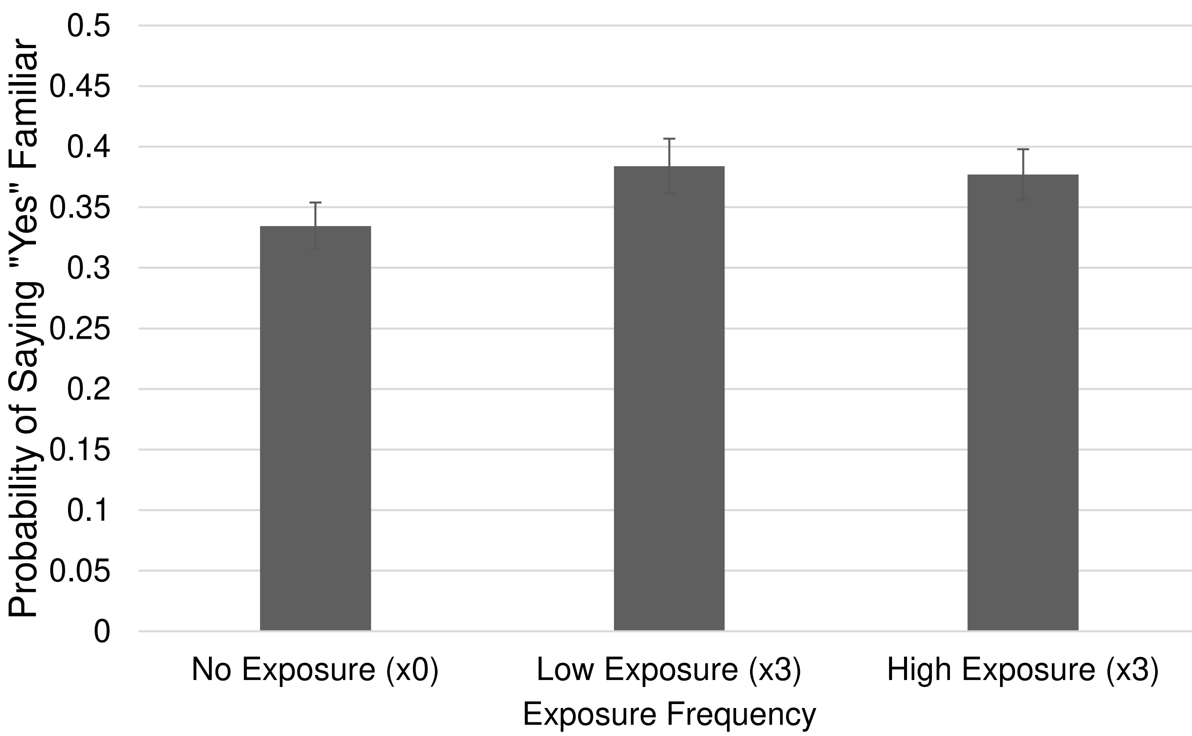

Figure 12. Probability of judging a test song containing familiarized rhythm sequences as familiar.

To assess how exposure and type of feature studied affected familiarity judgements, a 2 x 2 Exposure Frequency (Low Exposure x1, High Exposure x3) x Feature-type (Tone, Rhythm) repeated-measures ANOVA was conducted, revealing a marginally significant main effect of feature-type, $F(1, 111) = 3.86$, $MSE = .02$, $p = .052$ (see Figure 13).

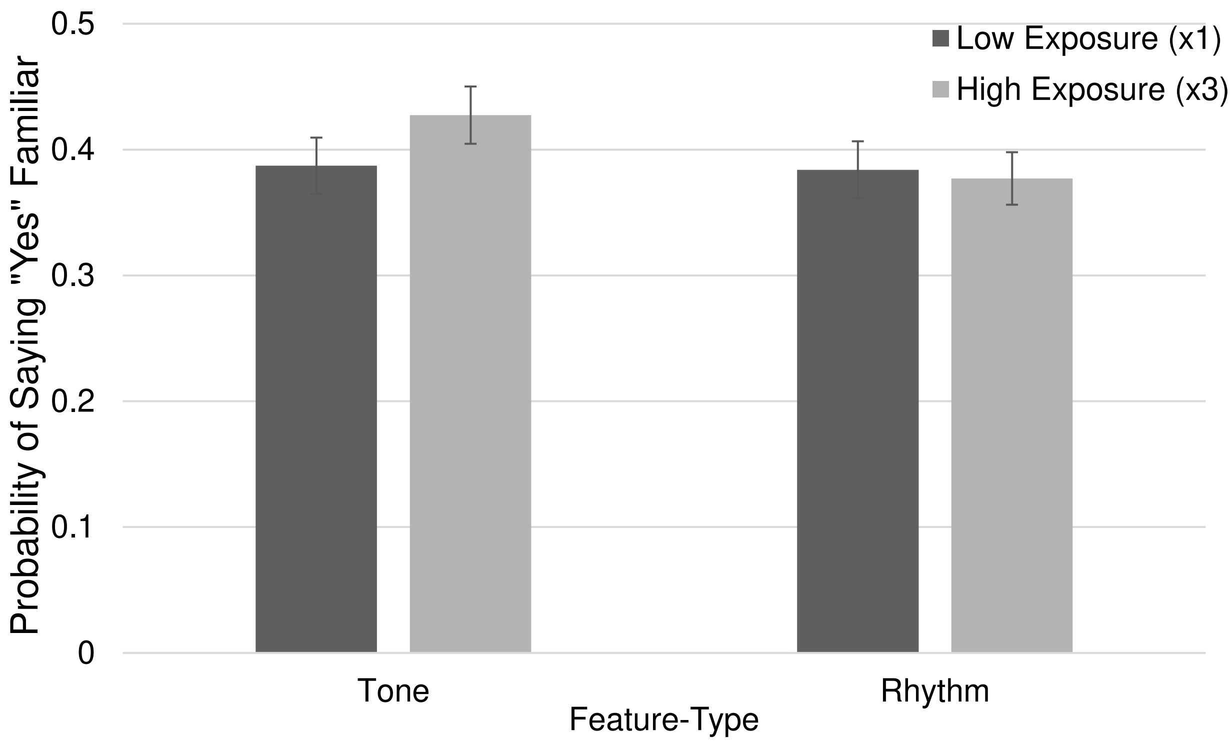

Figure 13. Probability of judging an unaltered song clip as subjectively familiarity given feature-type and exposure frequency.

When judging an unaltered song clip as subjectively familiar, participants were more likely to judge song clips containing familiarized tonal sequences presented three times at study as subjectively familiar than unaltered song clips containing familiarized rhythms presented three times at study, $t(111) = 2.69$, $SE = .02$, $p = .008$, $d = .22$. However, there was no main effect of Exposure Frequency, $F(1, 111) = 1.25$, $MSE = .03$, $p = .265$, very likely because there was a marginally significant interaction, F(1,

111) = 3.52, *MSE* = .02, *p* = .063 such that there was only difference between high and low exposure in the tone condition and not the rhythm condition.

Probability of Déjà Entendu

Participants were more likely to experience déjà entendu if the unaltered song clip contained a familiarized feature from study (*M* = .58, *SD* = .17) than if the unaltered song clip did not (*M* = .55, *SD* = .17), *t*(111) = 3.54, *SE* = .01, *p* = .001, *d* = .18.

As done in Experiment 2, the specific feature exposed during the study phase was next assessed. Focusing just on songs corresponding to familiarized tonal sequences, a repeated-measures ANOVA revealed a significant effect of exposure frequency, *F*(2, 222) = 6.86, *MSE* = .02, *p* = .001, η_p^2 = .06. In congruence with Experiment 2, there was no increased probability of experiencing déjà entendu for unaltered song clips that contained a familiarized tonal sequence presented once at study (*M* = .57, *SD* = .22) compared to unaltered song clips that contained no familiarized features (*M* = .55, *SD* = .17), *t*(111) = 1.64, *SE* = .01, *p* = .103. However, compared to unaltered song clips containing no familiarized features, when exposure frequency to the tonal sequence was increased to three instances, participants were significantly more likely to report feeling a sense of déjà entendu (*M* = .61, *SD* = .22), *t*(111) = 3.58, *SE* = .02, *p* = .001, *d* = .31. When comparing unaltered song clips that did contain familiarized tonal sequences, there was a significant difference in the probability of reporting déjà entendu for song clips that contained a familiarized tonal sequence exposed once compared to three times, *t*(111) = 2.06, *SE* = .02, *p* = .042, *d* = .16.

Turning to assess the effects of exposure frequency on the probability of reporting déjà entendu for songs corresponding to familiarized rhythms, a repeated-measures ANOVA was conducted. While there was a significant effect of exposure frequency on reports of déjà entendu for unaltered song clips corresponding to familiarized tonal sequences, the same was not true for songs corresponding to familiarized rhythms, $F(2, 222) = 1.73$, $MSE = .02$, $p = .180$. A paired-sample t-test did reveal a marginally significant difference between songs whose rhythms were heard once at study ($M = .58$, $SD = .21$) and unaltered song clips not studied at all, $t(111) = 1.84$, $SE = .014$, $p = .069$, $d = .13$. There was also a marginally significant difference between unaltered song clips studied three times ($M = .57$, $SD = .20$) and unaltered song clips not studied at all, $t(111) = 1.74$, $SE = .01$, $p = .085$, $d = .12$. However, there was no difference between song clips studied once or three times, $t(111) = .12$, $SE = .02$, $p = .905$. These findings are similar to those of Experiment 2. While the current experiment used slightly different test stimuli (songs were shortened to allow for contour prediction, which subsequently reduced the amount of feature overlap between study and test), the findings still suggest that tonal information is more influential on one's subjective sense of déjà entendu, perhaps due to tonal information being a "richer" feature.

To examine the differing contributions of features on the probability of reporting déjà entendu, a 2 x 2 Exposure Frequency (Low Exposure x1, High Exposure x3) x Feature-type (Tone, Rhythm) repeated-measures ANOVA was conducted. There was no significant main effect of feature-type, $F(1, 111) = 1.58$, $MSE = .02$, $p = .212$ (see Figure 14). There was also no significant main effect of exposure frequency, $F(1, 111) = 1.98$, $MSE = .02$, $p = .162$. Likewise, there was no significant interaction, $F(1, 111) = 2.33$, $MSE = .02$, $p = .130$.

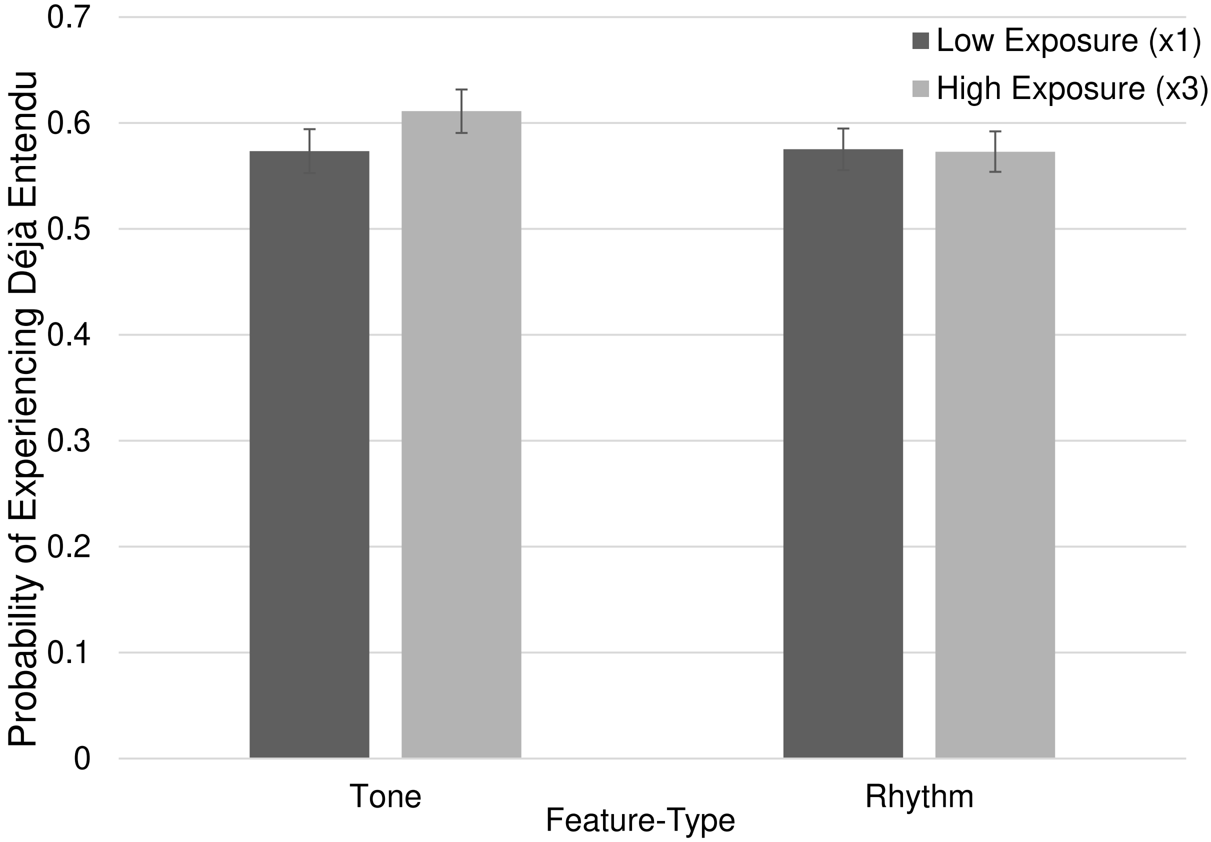

Figure 14. The probability of experiencing déjà entendu given feature-type and exposure frequency.

Perhaps the lack of effects found in the previous analyses is due to the unconsidered component of familiarity. As seen in McNeely-White and Cleary (2019), the RWI effect is dependent upon the presence of déjà entendu, such that participants were able to discriminate between studied and unstudied songs using subjective familiarity and déjà entendu. Based on this, perhaps the type of feature and exposure frequency do indeed have an effect on participants' déjà entendu experiences but are only evident when participants judge a song to be subjectively familiar. A simple paired-samples *t*-test indicated that participants were significantly more likely to experience déjà entendu when the unaltered song clip was judged as subjectively familiar (M = .75, *SD* = .25) compared to when it was not judged as subjectively familiar (*M* = .43, *SD* = .21), *t*(111) = 9.66, *SE* = .03, *p* < .001, *d* = 1.39 (see Figure 15).

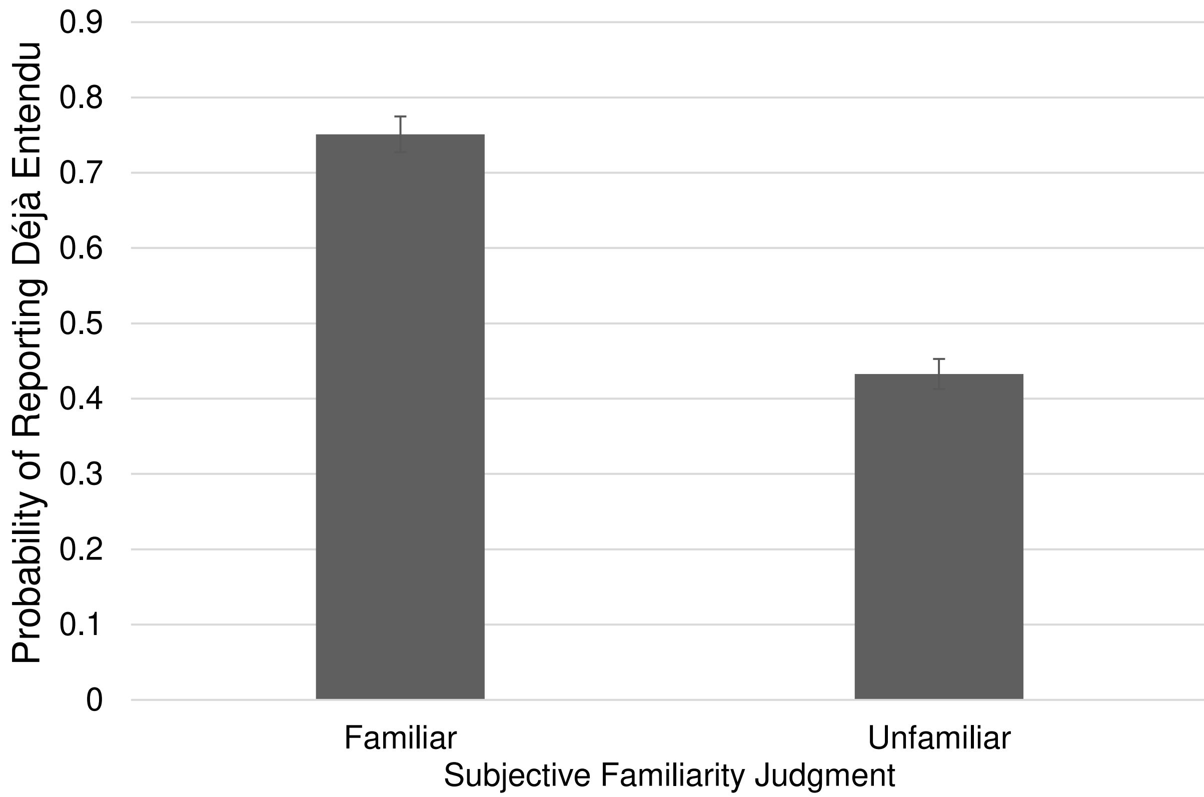

Figure 15. The probability of experiencing déjà entendu based on participants' subjective familiarity judgments. When an unaltered song clip was judged as subjectively familiar, participants were significantly more likely to report experiencing a sense of déjà entendu.

To address this question, a 2 x 2 Feature-Type (Tone, Rhythm) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted on the probability of experiencing déjà entendu when participants judged the song to be subjectively familiar. There was no main effect of feature-type, *F*(1, 90) = .78, *MSE* = .04, *p* = .381, or of exposure frequency, *F*(1, 90) = .51, *MSE* = .04, *p* = .478 (note that 21 people were lost from the analysis). There was no significant interaction, *F*(1, 90) = .47, *MSE* = .05, *p* = .494. The lack of significance may be in part due to the number of participants lost from the analysis.

As the above mentioned analyses have not yielded conclusive evidence on the nature and origins of déjà entendu, aside from it occurring more frequently for items containing experimentally familiarized features and for items that have been subjectively judged as familiar, an additional 2 x 3 Familiarity Judgment (Familiar, Unfamiliar) x Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted on the probability of experiencing déjà entendu. As the unique contributions of tonal and rhythmic features are somewhat mixed, the current analysis was focused on exposure frequency and subjective familiarity. A significant main effect of exposure frequency was found, $F(2, 198) = 4.54$, $MSE = .03$, $p = .012$, $\eta_p^2 = .04$ (see Figure 16; note that 12 participants were lost from the analyses).

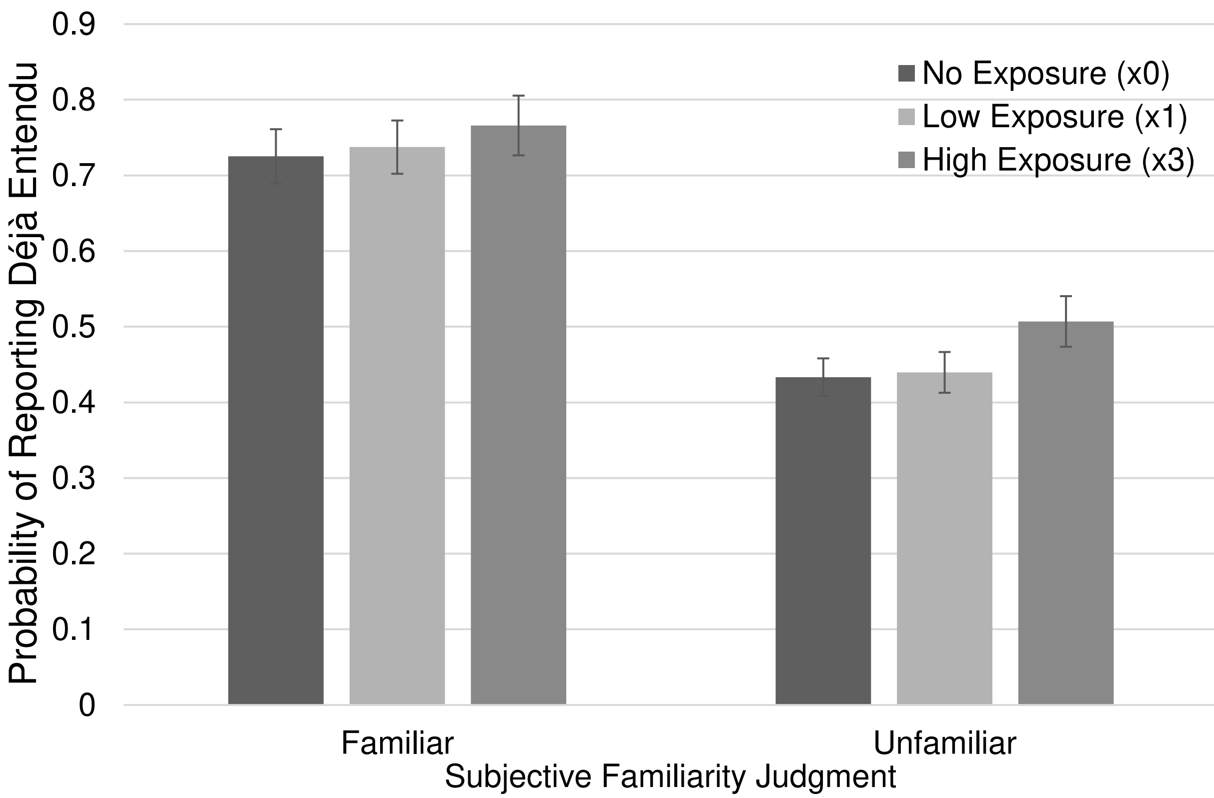

Figure 16. The probability of experiencing déjà entendu based on exposure frequency and participants' subjective familiarity judgments.

When judging an unaltered song clip as unfamiliar, participants were more likely to experience déjà entendu for song clips that corresponded to familiarized features presented three times at study (*M* = .50, *SD* = .31) than for song clips which did not contain familiarized features from study (*M* = .43, *SD* = .21), *t*(99) = 3.14, *SE* = .23, *p* = .002, *d* = .25. Upon comparing songs which were judged as subjectively unfamiliar but contained familiarized features, participants were more likely to experience déjà entendu for unaltered song clips containing familiarized features presented three times at study compared to only once (*M* = .44, *SD* = .24), *t*(99) = 2.81, *SE* = .02, *p* = .006, *d* = .21. However, when subjectively judged as familiar, participants' probabilities of experiencing déjà entendu did not differ as a function of exposure frequency (*p*'s > .05).

A significant main effect of subjective familiarity judgment was also found, *F*(1, 99) = 65.62, *MSE* = .19, *p* < .001, η_p^2 = .40. For unaltered song clips that did not contain experimentally familiarized features, participants were more likely to experience déjà entendu for song clips that were judged as subjectively familiar (*M* = .73, *SD* = .28) compared to song clips that were not, *t*(99) = 8.12, *SE* = .38, *p* < .001, *d* = 1.23. Additionally, for unaltered song clips that contained familiarized features presented once at study, participants were more likely to experience déjà entendu for song clips that were judged as subjectively familiar (*M* = .75, *SD* = .21) compared to songs that were not, *t*(99) = 8.03, *SE* = .39, *p* < .001, *d* = 1.21. When exposure to features was increased to three instances during the study phase, participants were more likely to experience déjà entendu for song clips that were judged as subjectively familiar (*M* = .76, *SD* = .32) compared to song clips that were not judged as subjectively familiar, *t*(99)

= 5.64, *SE* = .05, *p* < .001, *d* = .82. There was no significant interaction, *F*(2, 198) = 1.60, *MSE* = .03, *p* = .205.

Feelings of Prediction for Song Contour

Turning now to the data of most interest to the current experiment, feelings of prediction were assessed using a paired-samples *t*-test. While experiencing déjà entendu, participants were significantly more likely to report feelings of prediction (*M* = .76, *SD* = .19) compared to when they were not experiencing déjà entendu (*M* = .25, *SD* = .26), *t*(111) = 18.14, *SE* = .03, *p* < .001, *d* = 2.25 (see Figure 17). This finding is similar to that of work on déjà vu that has shown that participants are more likely to experience feelings of prediction for the unfolding event when they are in a déjà vu state (e.g., Cleary & Claxton, 2018; Cleary et al., 2018).

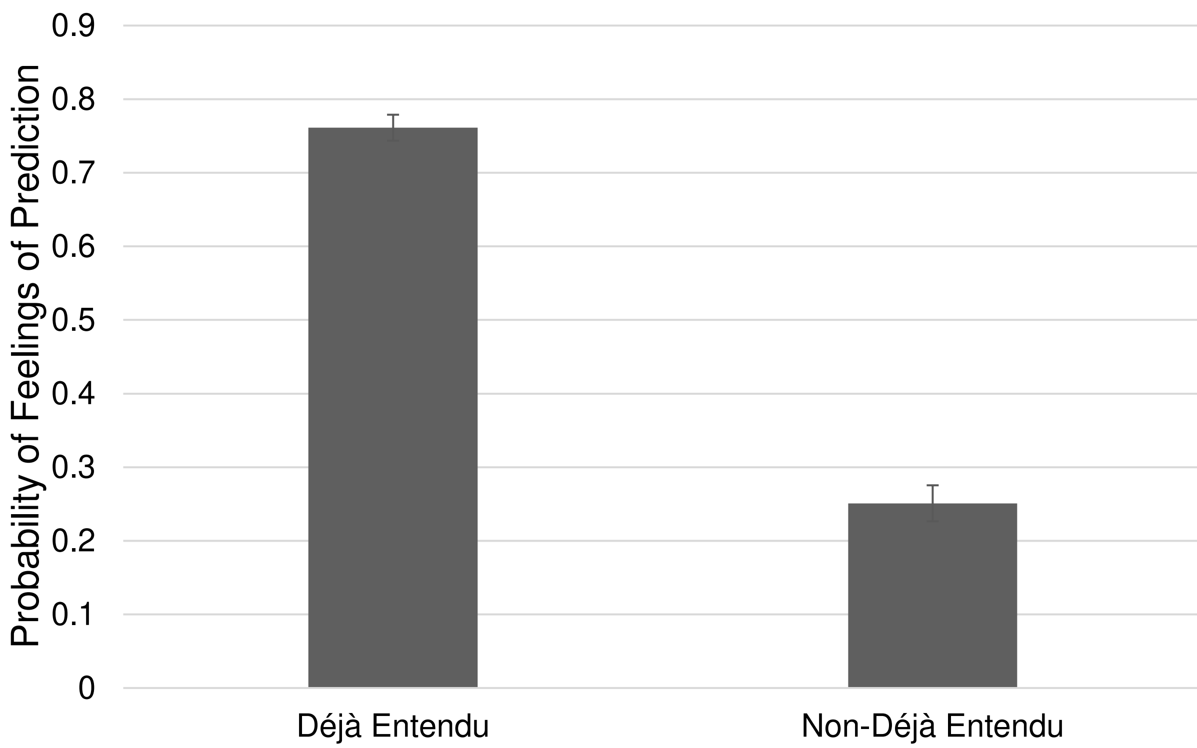

Figure 17. Probability of experiencing feelings of prediction given déjà entendu state.

However, despite participants feeling as if they could predict whether the proceeding note would go up or down in contour, regardless of whether they were experiencing déjà entendu, they were not above chance (.50) in their predictions (M = .50, SD = .08), t(111) = .21, p = .834. Furthermore, regardless of déjà entendu state or presence of feelings of prediction, participants' overall accuracy was not above chance (.50) for correctly predicting the proceeding note (M = .50, SD = .05), t(111) = .55, p = .581. To further compare the nature of déjà entendu to that of déjà vu in regard to feelings of prediction, Cleary and Claxton (2018) found no differences in accuracy of predictions even when participants had actually seen how the event unfolded at study. To examine whether the same illusory feelings of prediction are present in the current study, a repeated-measures ANOVA was conducted on whether exposure frequency (No Exposure x0, Low Exposure x1, High Exposure x3) had an effect on participants' accuracy when experiencing feelings of prediction. There was no effect of exposure frequency on participants' accuracy of prediction when they experienced feelings of prediction, F(2, 220) = 1.15, MSE = .02, p = .317 (note that one participant was lost from the analysis). Participants were not above chance (.50) in their accuracy of predictions when the unaltered song clip did not contain familiarized features (M = .50, SD = .14), t(110) = -.17, p = .87, when the song clip contained a feature familiarized once (M = .50, SD = .15), t(110) = -4.39, p = .661, or when the song clip contained a feature familiarized three times at study (M = .52, SD = .17), t(110) = 1.37, p = .173. These findings demonstrate that déjà entendu, like déjà vu, is associated with illusory feelings of prediction, as participants are no more accurate in their predictions even when the true outcome of the unfolding event was previously encountered at study. Participants are biased to believe that they can predict whether the next note will increase or decrease in contour.

To assess whether repeated exposure to the feature affected participants' feelings of prediction, a 2 x 3 Déjà Entendu State (Déjà entendu, Non-Déjà entendu) x Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted. There was no main effect of exposure frequency, $F(2, 220) = 1.17$, $MSE = .01$, $p = .313$ (see Figure 18), suggesting that additional exposure to the songs' features did not influence participants' subjective feelings of prediction for the contour (note that one participant was lost from the analyses).

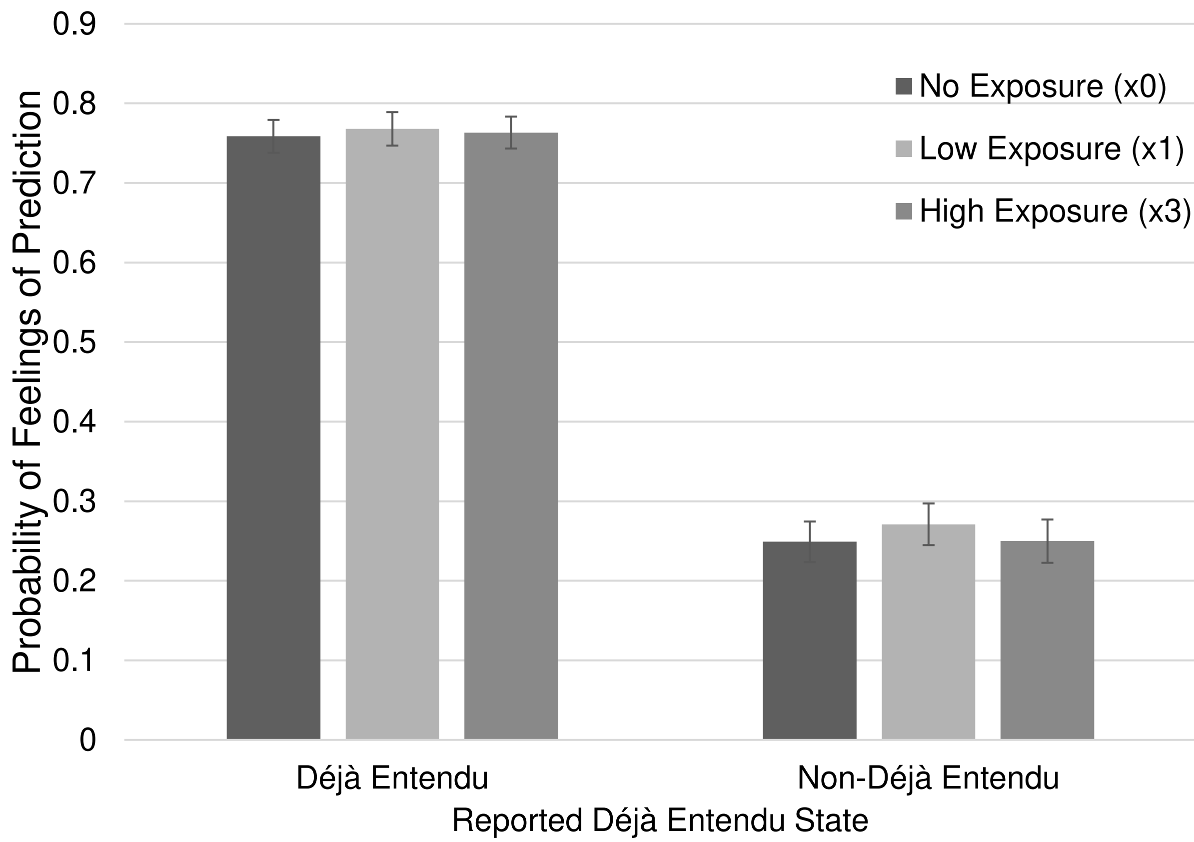

Figure 18. The probability of having a feeling of prediction for the contour of a song clip based on the exposure conditions the reported déjà entendu state. Overall, participants were more likely to have feelings of prediction when experiencing a déjà entendu state, regardless of the exposure condition.

However, there was a significant main effect of déjà entendu state, $F(1, 110) = 330.39$, $MSE = .13$, $p < .001$, $\eta_p^2 = .75$. When participants were experiencing déjà entendu, they were more likely to feel as if they could predict whether the next note would go up or down in contour compared to when they were not experiencing déjà entendu. There was no significant interaction between déjà entendu state and exposure frequency, $F(2, 220) = .31$, $MSE = .01$, $p = .731$.

Thus far, some differences have been observed in the contributions of tonal and rhythmic information in the probability of experiencing déjà entendu. These differences may also affect participants' feelings of prediction, as isolated tonal sequences do indeed carry contour information that could potentially be used to predict the contour of an unaltered song at a later time. A 2 x 2 x 2 Feature-Type (Tone, Rhythm) x Déjà Entendu State (Déjà entendu, Non-Déjà entendu) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted on the probability of participants reporting feelings of prediction (see Figures 19 and 20; note that 10 participants were lost from the analyses). The only significant main effect was that of déjà entendu state, $F(1, 101) = 255.95$, $MSE = .19$, $p < .001$, $\eta_p^2 = .72$. Regardless of the familiarized feature embedded within the song clip or the exposure frequency at study, participants were overall more likely to experience feelings of prediction if they were in a déjà entendu state compared to a non-déjà entendu state. There were no significant interactions (p's > .05).

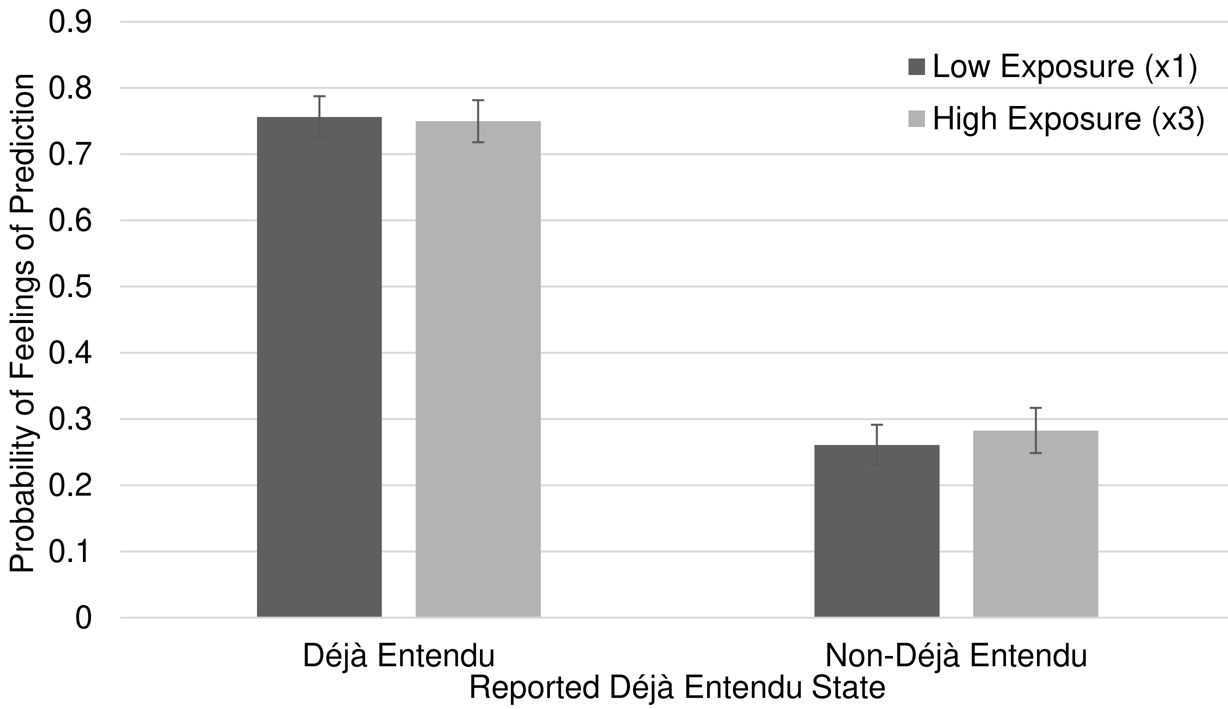

Figure 19. The probability of reporting feelings of prediction for song clips containing familiarized tonal sequences based on exposure frequency and déjà entendu report. Overall, participants were more likely to experience feelings of prediction during déjà entendu states.

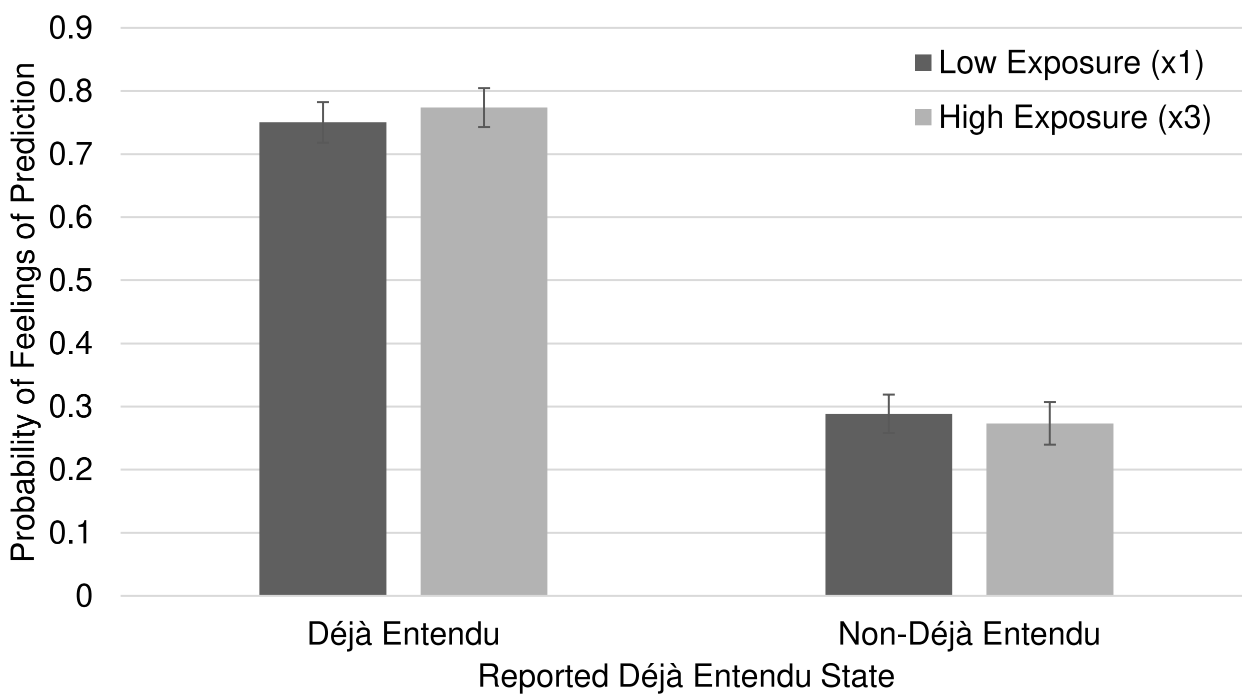

Figure 20. The probability of reporting feelings of prediction for song clips containing familiarized rhythms based on exposure frequency and déjà entendu report. Overall, participants were more likely to experience feelings of prediction during déjà entendu states.

To examine how subjective familiarity judgements might play a role in participants' reported feelings of prediction, a 3 x 2 Feature-Type (Tonal, Rhythmic, Unstudied) x Familiarity Judgment (Familiar, Unfamiliar) repeated-measures ANOVA was first conducted. A significant main effect of subjective familiarity judgment was found, $F(1, 104) = 35.92$, $MSE = .16$, $p < .001$, $\eta_p^2 = .26$ (see Figure 21; note that seven participants were lost from the analyses).

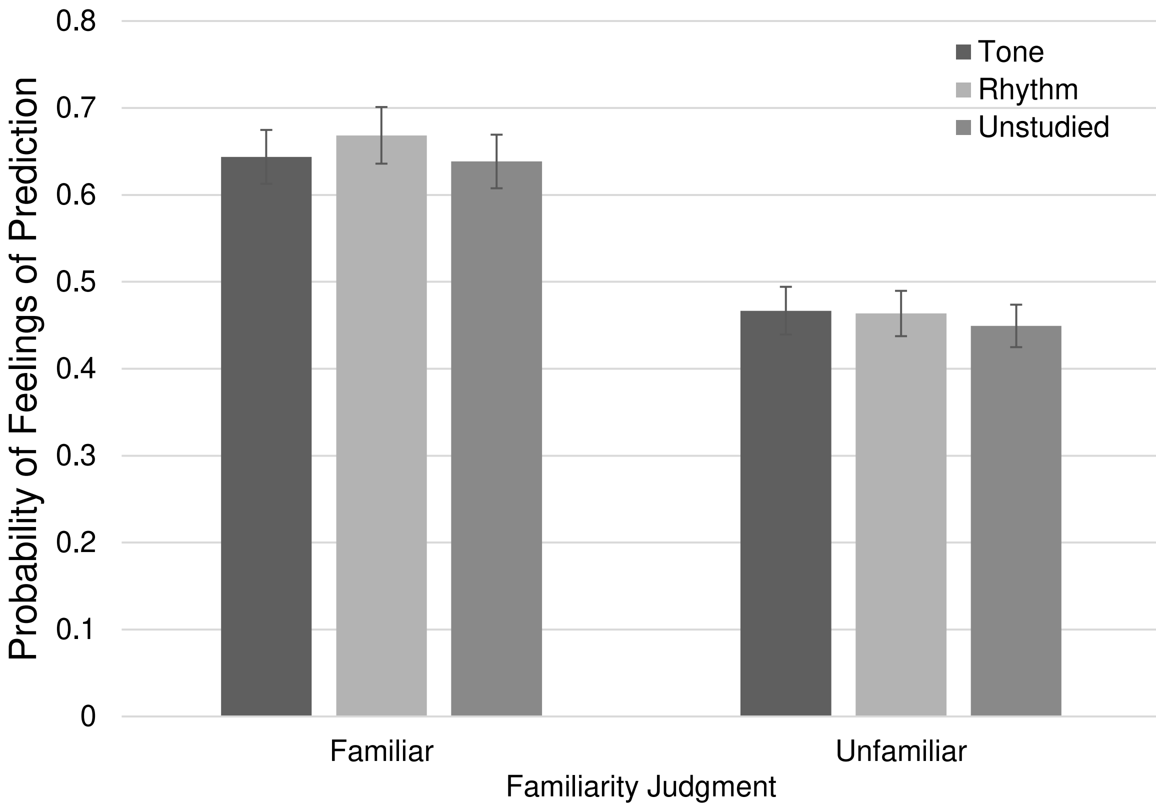

Figure 21. The probability of experiencing feelings of prediction based on the experimentally familiarized feature-type and participants' subjective familiarity judgments. Participants were more likely to experience feelings of prediction if the song clip was judged to be subjectively familiar, regardless of the familiarized feature-type.

When participants judged a song clip to be familiar, regardless of the familiarized feature, they were more likely to experience feelings of prediction than if the song clip was not judged as subjectively familiar. There was no significant main effect of feature-type, $F(2, 208) = 1.37$, $MSE = .02$, $p = .257$, or an interaction, $F(2, 208) = .40$, $MSE =$

.03, p = .670. This suggests that regardless of the familiarized feature-type, or whether there was even a familiarized feature present, participants were biased by the familiarity signal to believe that they could predict the contour of the song.

Finally, to assess the effects of déjà entendu states and subjective familiarity judgment on participants' feelings of prediction, a 2 x 2 Déjà Entendu State (Déjà entendu, Non-déjà entendu) x Familiarity Judgment (Familiar, Unfamiliar) repeated-measures ANOVA was conducted. A significant main effect of déjà entendu state was found, $F(1, 87) = 158.12$, $MSE = .10$, $p < .001$, $\eta_p^2 = .65$ (see Figure 22; note that 24 participants were lost from the analyses).

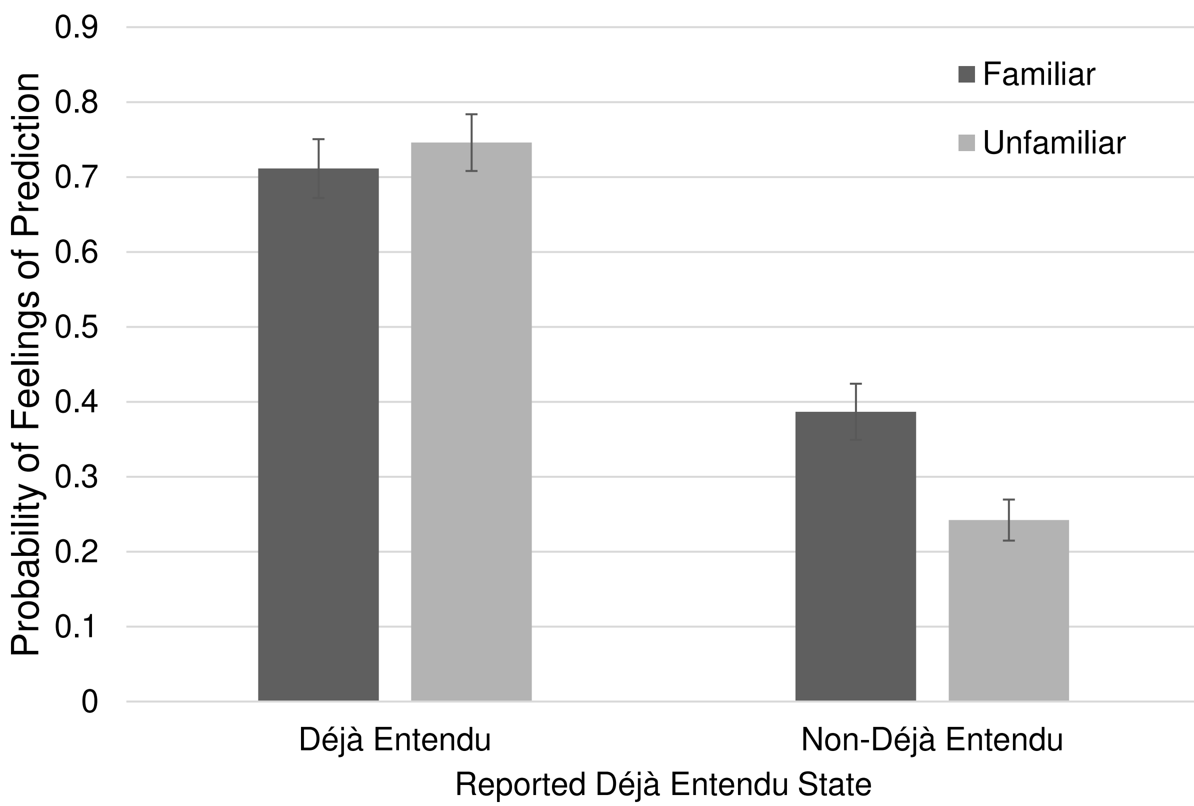

Figure 22. The probability of feelings of prediction based on reported déjà entendu state and subjective familiarity judgment.

When participants judged an unaltered song clip to be subjectively familiar, they were more likely to experience feelings of prediction when experiencing déjà entendu (M =

.71, *SD* = .25) than when not experiencing déjà entendu (*M* = .39, *SD* = .35), *t*(87) = 7.98, *SE* = .04, *p* < .001, *d* = 1.05. When participants judged an unaltered song clip to be subjectively unfamiliar, feelings of prediction were more likely to occur during déjà entendu states (*M* = .75, *SD* = .20) than non-déjà entendu states (*M* = .24, *SD* = .27), *t*(87) = 15.58, *SE* = .03, *p* < .001, *d* = 2.12. This suggests that déjà entendu is strongly correlated with feelings of prediction.

A significant main effect of subjective familiarity judgment was also found, *F*(1, 87) = 30.16, *MSE* = .02, *p* < .001, η_p^2 = .26. When participants were in a non-déjà entendu state, they were more likely to report feelings of prediction for unaltered song clips that were judged as subjectively familiar than for songs that were judged as subjectively unfamiliar, *t*(87) = 4.43, *SE* = .03, *p* < .001, *d* = .45. As suggested by Figure 20, there was also a significant interaction between subjectively familiarity judgment and reported déjà entendu state, *F*(1, 87) = 5.69, *MSE* = .05, *p* = .019, η_p^2 = .06. Although non-déjà entendu states were more likely to be associated with feelings of prediction when the song clip was judged as subjectively familiar compared to subjectively unfamiliar, the same was not true when participants were in a déjà entendu state. Instead, there was no difference in the probability of reporting feelings of prediction during déjà entendu states when the song clip was judged subjectively familiar compared to subjectively unfamiliar, *t*(87) = -1.51, *SE* = .02, *p* = .135. This may be in part due to déjà entendu being a stronger driver of feelings of prediction than participants subjective familiarity judgments. However, it is worthwhile to note that the means are in the opposite direction of what would be predicted, with déjà entendu states for subjectively unfamiliar songs being more probable to elicit feelings of prediction than déjà entendu states for subjectively familiar song clips.

Chapter 6 - Experiment 3b (Feelings of Prediction for Sound Location)

While the purpose of Experiment 3a was to assess familiarity and feelings of prediction with song sequences, there are theoretical reasons to suspect true prediction of song contour. In consideration of musical expectations, the contour of a song may be based upon the context and the preceding notes, which may allow for true prediction (Huran, 2006). While the results of Experiment 3a did not indicate a significant ability to predict even during instances of participants *feeling* they could, there is still the possibility that participants only felt as if they could predict because, based on Western tonal structure, this is potentially predictable. Therefore, the purpose of Experiment 3b was to create a scenario in which actual prediction cannot occur as the prediction decision will be truly unpredictable.

In Experiment 3b, participants were asked to predict the location of the next sound. This was be done by manipulating whether the song was played out of the left or right side of the headphones that participants was wearing or the speakers to which they were listening. As the design of Experiment 3a may have allowed participants to encode information that could have increased their abilities to predict the contour of the song, such as the isolated tonal sequences carrying the true contour, participants' predictive abilities may be due to recollection, not illusory feelings of prediction. Therefore, Experiment 3b required predictions that were truly random and cannot be due to recollection.

Method

Participants

Participants were 117 undergraduates from Colorado State University who received course credit for participation. However, due to not completing the experiment or speakers malfunctioning, 10 participants were excluded. A power analysis using G-Power software indicated that a sample size of 84 is sufficient to detect a medium effect size (d = .40), assuming an alpha of .05, power of .95, and a repeated-measures ANOVA.

Materials

The stimuli were the same as those used in Experiment 3a. To manipulate the location presentation of each note, 12 permutations were created, containing random patterns of Left/Right speaker. Adobe Audition 3.0 software was used to manipulate the sound channels of the test songs, with each song being matched to one of the 12 permutations.

Procedure

Experiment 3b followed the procedure of Experiment 3a; however, instead of asking participants if they felt that they could predict whether the proceeding note would go up or down in pitch, participants were asked if they felt that they could predict whether the proceeding note would be played out of the left or right side of the headphones or speakers (y=yes, n=no).

Results

Identification Rates

See Table 3 for the proportions of songs identified at study and test. Overall, participants' identification of songs at study was low. When a song was presented as an isolated rhythm, participants were more likely to identify the song if it was presented three times compared to if it was presented once, $t(108) = 2.39$, $SE = .003$, $p = .019$. There was no difference, though, when comparing songs that were presented at isolated tonal sequences, as participants' identification rates for isolated tonal sequences presented three times were not significantly higher than that of the identification rates for isolated tonal sequences presented once, $t(108) = .70$, $SE = .005$, $p = .486$. In examining differences in the proportions of songs based on feature-type, a significant difference was found for songs that were studied once as an isolated rhythm compared to an isolated tonal sequence, $t(108) = 2.72$, $SE = .004$, $p = .008$. When the exposure to features was increased to three instances, there was no significant difference among identification rates based on feature-type, with isolated tonal sequences being identified at a similar rate as the isolated rhythms, $t(108) = 1.01$, $SE = .004$, $p = .315$.

Table 3.
Proportions of songs identified from study and test.

	Study		Test	
	M	*SD*	*M*	*SD*
Overall	.007	.008	.16	.10
Rhythm x1	.003	.013	.17	.14
Rhythm x3	.011	.034	.17	.13
Tone x1	.013	.035	.15	.13
Tone x3	.03	.035	.16	.15

At test, participants were not more likely to identify unaltered song clips that contained familiarized features from study (M = .17, SD = .10) compared to unaltered song clips that did not contain familiarized features from study (M = .17, SD = .11), $t(108) = .33$, $SE = .01$, $p = .741$. When considering feature-type and exposure frequency, participants' identification rates for unaltered song clips that contained familiarized features did not differ as a function of the type of feature studied or the exposure condition (p's > .05).

The Recognition Without Identification Effect

Participants were more likely to judge an unaltered song clip as familiar if it contained unidentified musical features that were experimentally familiarized at study (M = .34, SD = .21) compared to if it did not contain familiarized features from study (M = .29, SD = .21), $t(108) = 5.14$, $SE = .01$, $p < .001$, $d = .24$. When considering the type of feature presented at study, a repeated-measures ANOVA on unaltered song clips corresponding to isolated tonal sequences presented at study showed a significant effect, $F(2, 216) = 19.02$, $MSE = .02$, $p < .001$, $\eta_p^2 = .15$ (see Figure 23). When participants heard unaltered song clips containing familiarized tonal sequences presented once at study (M = .36, SD = .26), they were significantly more likely to judge the unaltered song clips as subjectively familiar compared to if the unaltered song clip did not contain familiarized features from study, $t(108) = 4.78$, $SE = .01$, $p < .001$, $d = .28$. When comparing unaltered song clips that did not contain any familiarized features from study to unaltered song clips that contained unidentified tonal sequences presented three times at study, participants were significantly more likely to judge the unaltered song clips containing the tonal sequences as subjectively familiar (M = .40,

SD = .25), t(108) = 6.07, SE = .02, p < .001, d = .48. Additionally, participants were more likely to judge an unaltered song clip as subjectively familiar when the isolated tonal features that were unidentified at study were presented three times compared to only once, t(108) = 2.12, SE = .22, p = .036, d = 0.18.

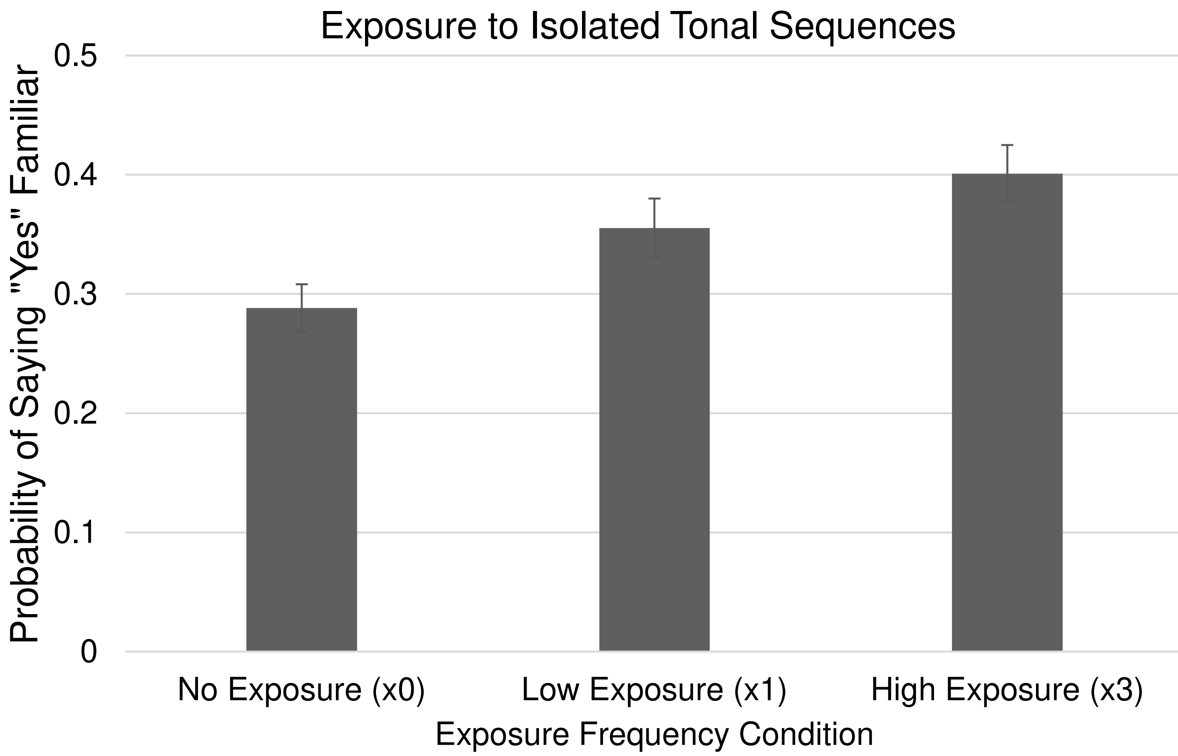

Figure 23. Probability of judging an unaltered song clip containing experimentally familiarized tonal sequences as subjectively familiar. As exposure to the tonal features increased, participants were more likely to judge the clip as familiar.

When considering participants familiarity judgments for songs corresponding to unidentified isolated rhythms presented at study, a repeated-measures ANOVA revealed a significant effect, F(2, 216) = 7.06, MSE = .012, p = .001, η_p^2 = .06 (see Figure 24). Unlike prior experiments, there was no significant difference in the probability of judging an unaltered test song clip as subjectively familiar if it contained a familiarized rhythm presented once at study (M = .28, SD = .24) compared to if it did not contain any familiarized features, t(108) = .77, SE = .01, p = .443. However, when exposure was increased to three instances, participants were significantly more likely to judge the unaltered song clip as subjectively familiar (*M* = .33, *SD* = .23) compared to if it did not contain any familiarized features, $t(108) = 3.02$, *SE* = .01, $p = .003$, $d = .23$. When comparing unaltered song clips that did contain unidentified rhythms that were familiarized at study, participants were more likely to judge an unaltered song clip as familiar if it contained a rhythm familiarized three times as opposed to only once, $t(108) = 3.30$, *SE* = .02, $p = .001$, $d = .22$.

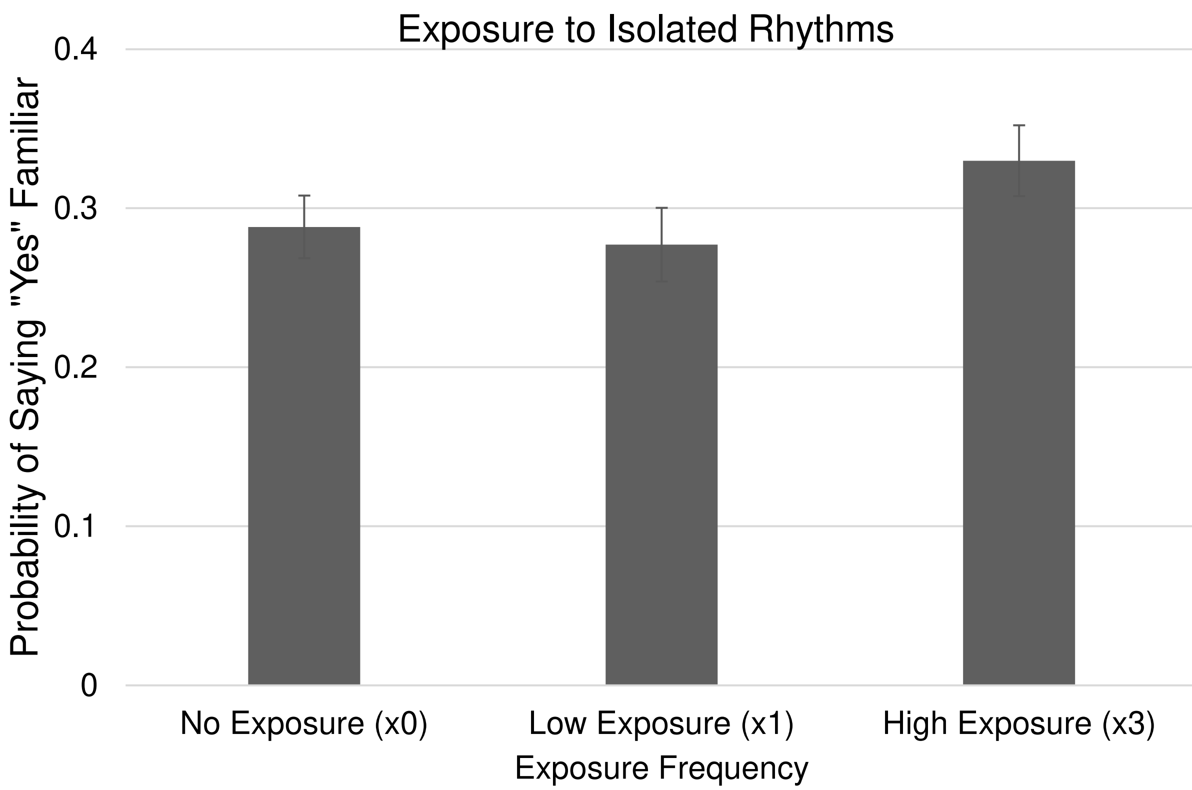

Figure 24. Probability of judging an unaltered song clip containing experimentally familiarized rhythms as subjectively familiar. When exposure to the isolated rhythms at study was high (three instances), participants were more likely to judge the clip as familiar.

To assess how exposure and feature-type affected subjective familiarity judgments, a 2 x 2 Exposure Frequency (Low Exposure x1, High Exposure x3) x Feature-type (Tone, Rhythm) repeated-measures ANOVA was conducted, revealing a significant effect of feature-type, $F(1, 108) = 32.36$, $MSE = .02$, $p < .001$, $\eta_p^2 = .23$. (see Figure 25).

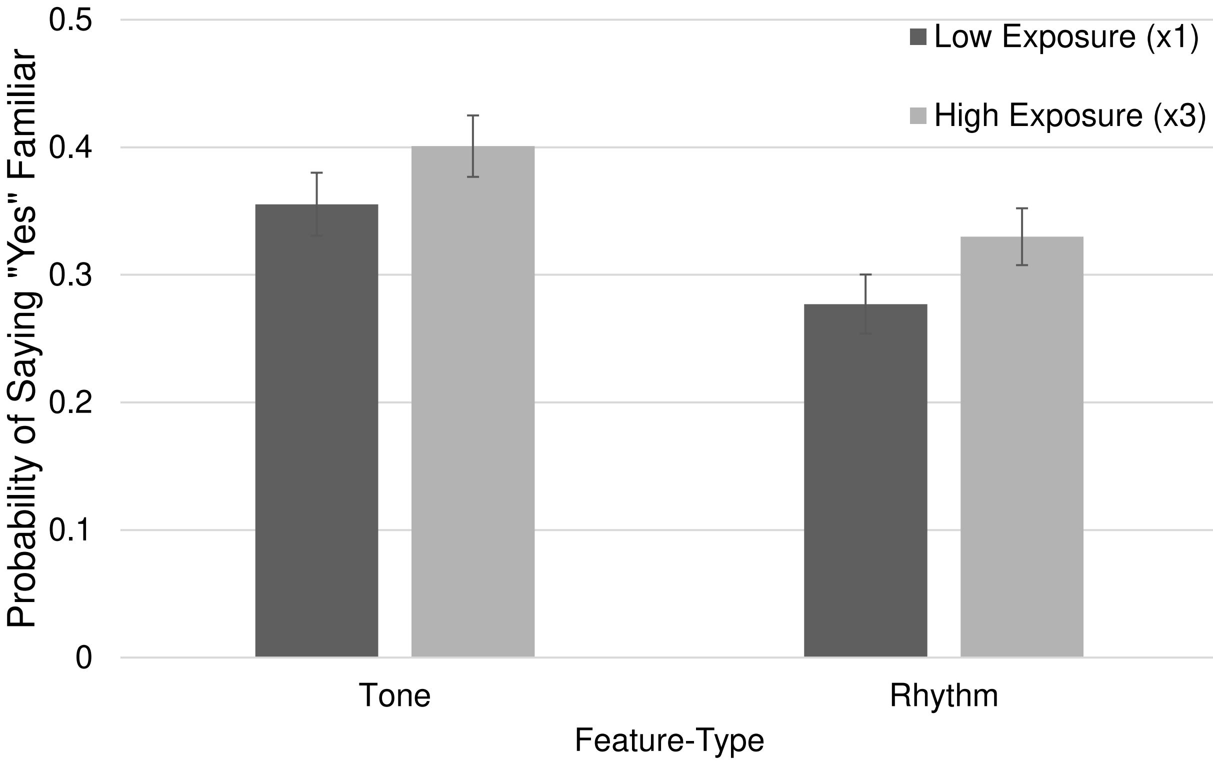

Figure 25. The probability of judging an unaltered song clip as subjectively familiar given feature-type and exposure frequency.

When there was only one instance of feature exposure at study and that feature was unidentified, participants were more likely to judge the song clip as subjectively familiar if it contained a familiarized tonal sequence compared to a familiarized rhythm, $t(108) = 4.80$, $SE = .02$, $p < .001$, $d = .31$. A similar pattern was also found for song clips containing features that were presented three times at study, with participants being more likely to judge the song clip as familiar if it contained an unidentified tonal feature as opposed to a rhythm, $t(108) = 3.51$, $SE = .02$, $p = .001$, $d = .29$. There was also a significant main effect of exposure frequency, $F(1, 108) = 12.54$, $MSE = .02$, $p = .001$, $\eta_p^2 = .10$. When participants heard unaltered song clips containing unidentified familiarized rhythms, they were more likely to judge the song clip as subjectively familiar if the rhythm was exposed three times compared to only once, $t(108) = 3.30$, $SE = .02$, $p = .001$, $d = .22$. Additionally, when participants heard unaltered song clips containing familiarized rhythms, they were more likely to judge the song clip as subjectively familiar if the tonal sequence was exposed three times compared to only once, $t(108) = 2.12$, $SE = .02$, $p = .036$, $d = .18$. There was no significant interaction, $F(1, 108) = .08$, $MSE = .02$, $p = .779$, suggesting that unaltered song clips that contain familiarized tonal sequences are overall more likely to elicit subjective familiarity compared to rhythms, and that as exposure frequency increases, so does the probability of judging an unaltered song clip to be subjectively familiar.

The Déjà Entendu Phenomenon

Participants were marginally more likely to experience déjà entendu if the unaltered song clip contained an unidentified feature from study ($M = .48$, $SD = .22$) compared to if it did not contain any familiarized features ($M = .46$, $SD = .21$), $t(108) = 1.86$, $SE = .01$, $p = .066$, $d = .09$. As previously done, the effects of the specific feature exposed at study were next examined. Focusing on trials in which an isolated tonal sequence had been previously familiarized and was unidentified at study, a repeated-measures ANOVA indicated that there was a significant effect, $F(2, 216) = 8.27$, $MSE = .01$, $p < .001$, $\eta_p^2 = .07$. When participants heard unaltered song clips that contained an unidentified tonal sequence presented once at study, they were more likely to have a sense of déjà entendu ($M = .49$, $SD = .21$) compared to if the song clip did not contain any familiarized features ($M = .46$, $SD = .21$), $t(108) = 2.10$, $SE = .01$, $p = .038$, $d = .12$. Additionally, when exposure frequency was increased to three instances, participants were more likely to have a sense of déjà entendu (*M* = .52, *SD* = .25) compared to if there were no instances of exposure, $t(108) = 4.51$, $SE = .01$, $p < .001$, $d = .26$. There was a marginally significant difference between song clips that contained tonal features presented once versus three times, $t(108) = -1.85$, $SE = .02$, $p = .067$, $d = -.13$.

Now focusing on the probability of experiencing déjà entendu for unaltered song clips containing familiarized rhythms, there was no significant effect found, $F(2, 216) = 1.59$, $MSE = .02$, $p = .207$. Upon comparing conducting paired samples *t*-tests, there were no differences found among unaltered song clips that did not contain familiarized rhythms and those that contained familiarized rhythms presented once or three times (*p*'s > .10).

To examine the differing contributions of features on the probability of reporting déjà entendu, a 2 x 2 Feature-Type (Tone, Rhythm) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted. While there was no significant interaction, $F(1, 108) = .02$, $MSE = .022$, $p = .878$, there was a significant main effect of feature-type, $F(1, 108) = 17.22$, $MSE = .02$, $p < .001$, $\eta_p^2 = .14$ (see Figure 26). When participants were exposed to the feature once at study and were unable to identify it, they were significantly more likely to later have déjà entendu for the unaltered song clip at test if the feature presented was an isolated tonal sequence (*M* = .49, *SD* = .26) compared to an isolated rhythm (*M* = .44, *SD* = .24), $t(108) = 2.79$, $MSE = .02$, $p = .007$, $d = .21$. Likewise, when exposed to the feature three times at study, participants were more likely to have a sense of déjà entendu for unaltered whole songs that corresponded to familiarized tonal sequences (*M* = .52, *SD* = .25) compared to familiarized rhythms (*M* = .47, *SD* = .25), $t(108) = 2.61$, $SE = .02$, $p = .010$, $d = .20$.

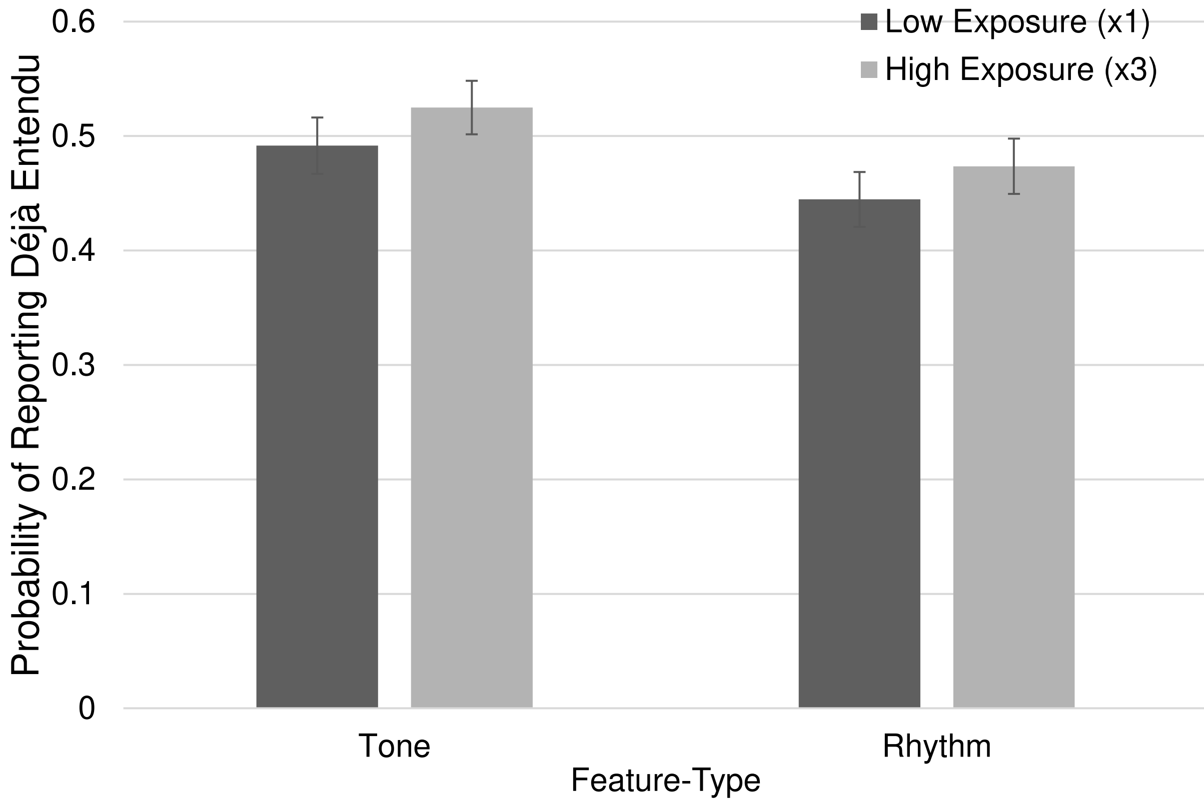

Figure 26. The probability of experiencing déjà entendu based on feature-type and exposure frequency condition. Overall, participants were more likely to experience déjà entendu for unaltered song clips containing familiarized tonal sequences compared to familiarized rhythms.

The repeated-measures ANOVA also indicated that there was a significant main effect of exposure frequency, $F(1, 108) = 6.08$, $MSE = .11$, $p = .015$, $\eta_p^2 = .05$. When participants heard unaltered song clips containing familiarized tonal sequences, there was a marginally significant increase in the probability of reporting déjà entendu for clips that contained a tonal sequence presented three times compared to only once, $t(108) = 1.85$, $SE = .02$, $p = .067$, $d = .13$. There was no difference in the probability of reporting déjà entendu for unaltered song clips that contained familiarized rhythms presented once versus three times at study, $t(108) = -1.46$, $SE = .02$, $p = .147$, $d = -0.12$.

As seen in prior experiments, the probability of experiencing déjà entendu is affected by the participant's subjective familiarity judgment of the unaltered song clip.

Indeed, in the current experiment, participants were significantly more likely to experience déjà entendu for unaltered song clips that were judged as subjectively familiar (*M* = .70, *SD* = .30) compared to subjectively unfamiliar (*M* = .35, *SD* = .22), *t*(106) = 11.07, *SE* = .03, *p* < .001, *d* = 1.29 (note that two participants were lost from the analysis). As done in Experiment 3a, a 2 x 3 Familiarity Judgment (Familiar, Unfamiliar) x Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted on the probability of experiencing déjà entendu. Unlike Experiment 3a, there was no significant main effect of exposure frequency, *F*(2, 190) = 1.96, *MSE* = .02, *p* = .144, η_p^2 = .02 (see Figure 27; note that 13 participants were lost from the analyses).

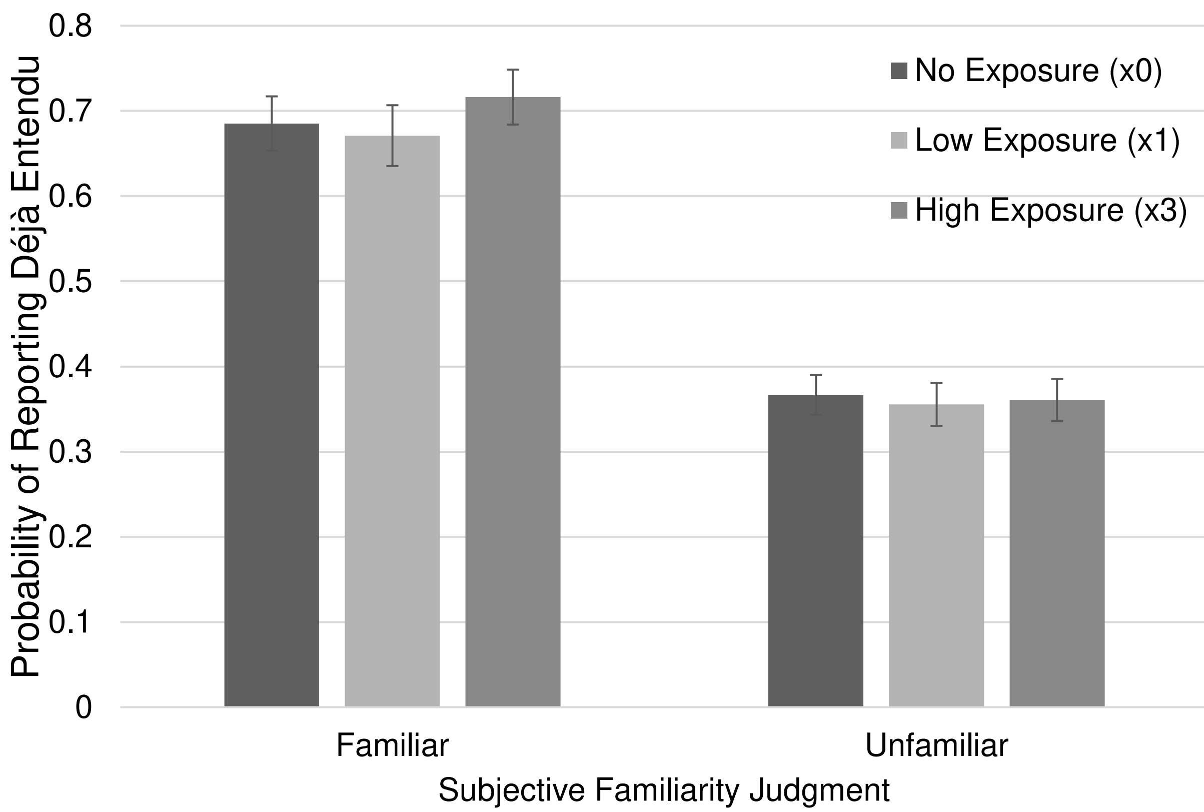

Figure 27. The probability of experiencing déjà entendu based on exposure frequency condition and participants' subjective familiarity judgments. Overall, participants were significantly more likely to experience déjà entendu if the unaltered song clip was judged as subjectively familiar, regardless of exposure frequency condition.

However, there was a significant main effect of familiarity judgment, $F(1, 95) = 102.11$, $MSE = .15$, $p < .001$, $\eta_p^2 = .52$. When an unaltered song clip did not contain any familiarized features from study, participants were significantly more likely to experience déjà entendu if they had judged the song to be subjectively familiar ($M = .69$, $SD = .31$) compared to subjectively unfamiliar ($M = .37$, $SD = .23$), $t(95) = 9.21$, $SE = .03$, $p < .001$, $d = 1.16$. When the frequency of exposure to the features at study was equal to one, participants were significantly more likely to experience déjà entendu if the unaltered song clip was judged as subjectively familiar ($M = .67$, $SD = .35$) compared to subjectively unfamiliar ($M = .36$, $SD = .25$), $t(95) = 8.02$, $SE = .39$, $p < .001$, $d = 1.03$. Finally, when there were three instances of exposure to the isolated feature at study, participants were also more likely to experience déjà entendu if the unaltered song clip had been judged as subjectively familiar ($M = .72$, $SD = .32$) compared to subjectively unfamiliar ($M = .36$, $SD = .24$), $t(95) = 9.81$, $SE = .04$, $p < .001$, $d = 1.26$. There was no interaction between familiarity judgement and exposure frequency, $F(2, 190) = 1.16$, $MSE = .02$, $p = .316$, $\eta_p^2 = .01$, suggesting that participants' subjective familiarity judgments are the primary influence on whether or not they will experience déjà entendu, regardless of the exposure frequency condition.

Probability of Feelings of Prediction

When participants were experiencing déjà entendu, they were significantly more likely to experience feelings of prediction for the location of the next note ($M = .62$, $SD = .28$) compared to when they were in non-déjà entendu ($M = .34$, $SD = .28$), $t(107) = 9.11$, $SE = .03$, $p < .001$, $d = 1.0$ (see Figure 28). However, due to the nature of the experimental design, these feelings are purely illusory, as there was no pattern to the note location. As discussed in the methods, each song followed a randomly generated permutation for whether the left or right speaker would produce the proceeding note.

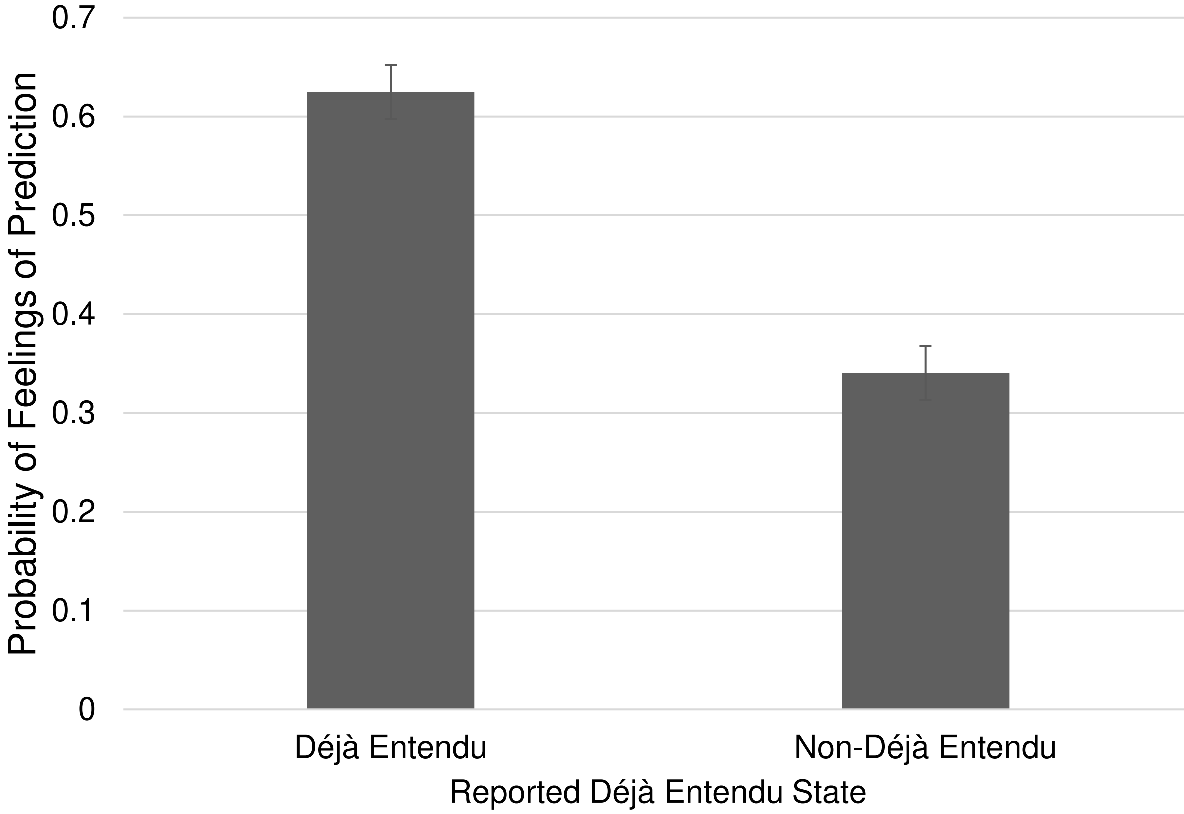

Figure 28. The probability of experiencing feelings of prediction given the reported déjà entendu state.

As was previously done in Experiment 3a to assess the effects of exposure frequency and déjà entendu on the probability of experiencing feelings of prediction, a 2 x 3 Déjà Entendu State (Déjà entendu, Non-déjà entendu) x Exposure Frequency (No Exposure x0, Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted. There was no significant main effect of exposure frequency condition, $F(2, 204) = .72$, $MSE = .02$, $p = .487$ (see Figure 29), suggesting that additional exposure to the unaltered song clip's features at study did not influence participants' subjective feelings of prediction for the location of the next note (note that six participants were lost from the analyses). However, there was a significant main effect of déjà entendu state, $F(1, 102) = 92.78$, $MSE = .14$, $p < .001$, $\eta_p^2 = .48$. When participants heard an unaltered song clip that did not contain any familiarized features from study, they were more likely to experience feelings of prediction if they were concurrently experiencing a sense of déjà entendu ($M = .63$, $SD = .27$) compared to if they were not experiencing a sense of déjà entendu ($M = .35$, $SD = .30$), $t(102) = 8.69$, $SE = .03$, $p < .001$, $d = .98$.

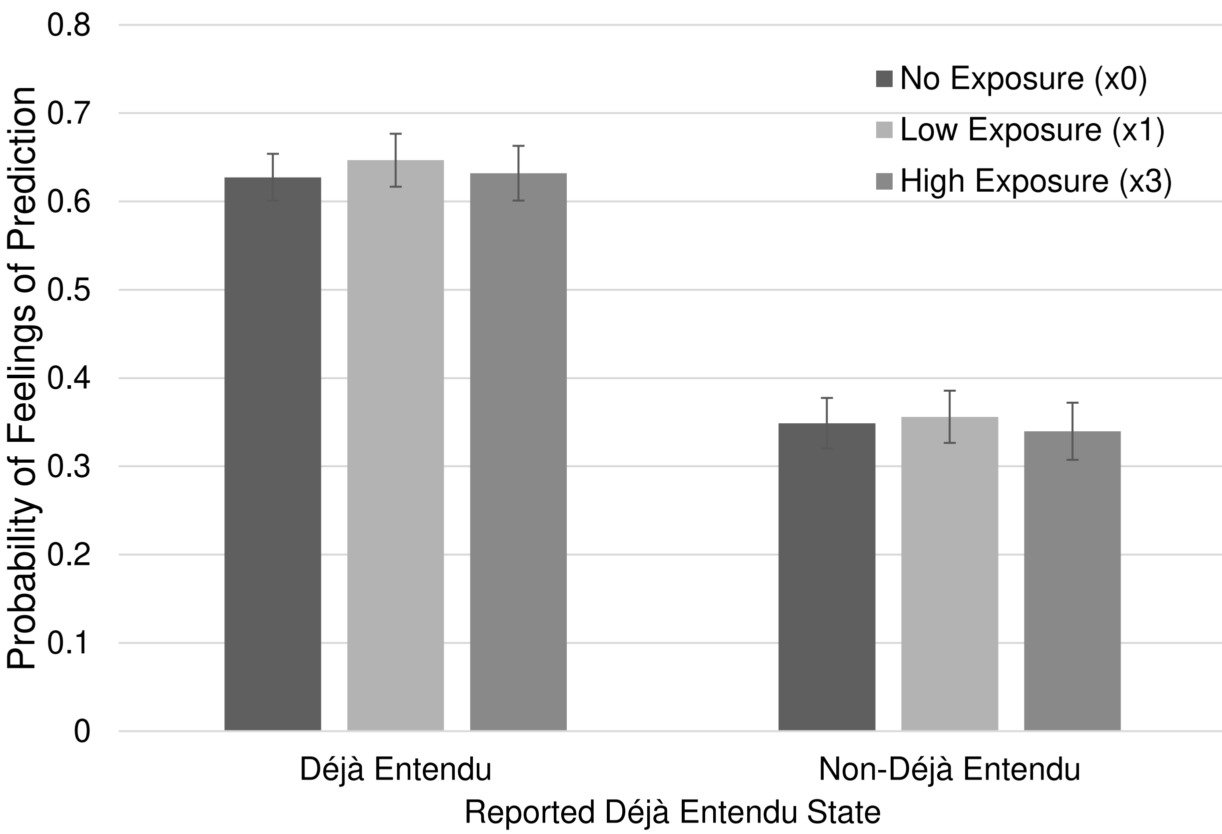

Figure 29. The probability of experiencing feelings of prediction for the location of the next note based on exposure frequency condition and the reported déjà entendu state. Overall, participants were more likely to have feelings of prediction when experiencing déjà entendu, regardless of the exposure frequency condition.

Participants were also more likely to experience feelings of prediction for unaltered song clips that corresponded to unidentified features presented once at study if they were in a déjà entendu state ($M = .65$, $SD = .30$) compared to a non-déjà entendu state ($M = .36$, $SD = .30$), $t(102) = 8.86$, $SE = .03$, $p < .001$, $d = .97$. Additionally, when participants heard unaltered song clips that corresponded to unidentified features presented three times at study, they were significantly more likely to experience feelings of prediction during déjà entendu (M = .63, SD = .32) compared to when they were not experiencing déjà entendu (M = .34, SD = .33), $t(102) = 8.30$, SE = .04, $p < .001$, d = .89. There was no significant interaction between déjà entendu state and exposure frequency condition, $F(2, 204) = .16$, MSE = .02, p = .849. Taken together, these results suggest that there is a strong correlation between feelings of prediction and déjà entendu states that is not significantly impacted by the experimentally manipulated exposure frequency condition.

To assess the differing contributions of tonal and rhythmic information in the probability of experiencing feelings of familiarity, a 2 x 2 x 2 Feature-Type (Tone, Rhythm) x Déjà Entendu State (Déjà entendu, Non-déjà entendu) x Exposure Frequency (Low Exposure x1, High Exposure x3) repeated-measures ANOVA was conducted. The only significant main effect was that of déjà entendu, $F(1, 85) = 68.81$, MSE = .21, $p < .001$, $\eta_p^2 = .45$ (see Figures 30 and 31; note that 23 participants were lost from the analyses). Regardless of the familiarized feature embedded within the unaltered song clip or the exposure frequency condition at study, participants were overall more likely to experience feelings of prediction if they reported being in a déjà entendu state.

A 3 x 2 Feature-Type (Tonal, Rhythmic, Unstudied) x Familiarity Judgment (Familiar, Unfamiliar) repeated-measures ANOVA was conducted to examine how familiarity judgments might play a role in participants’ reported feelings of prediction.

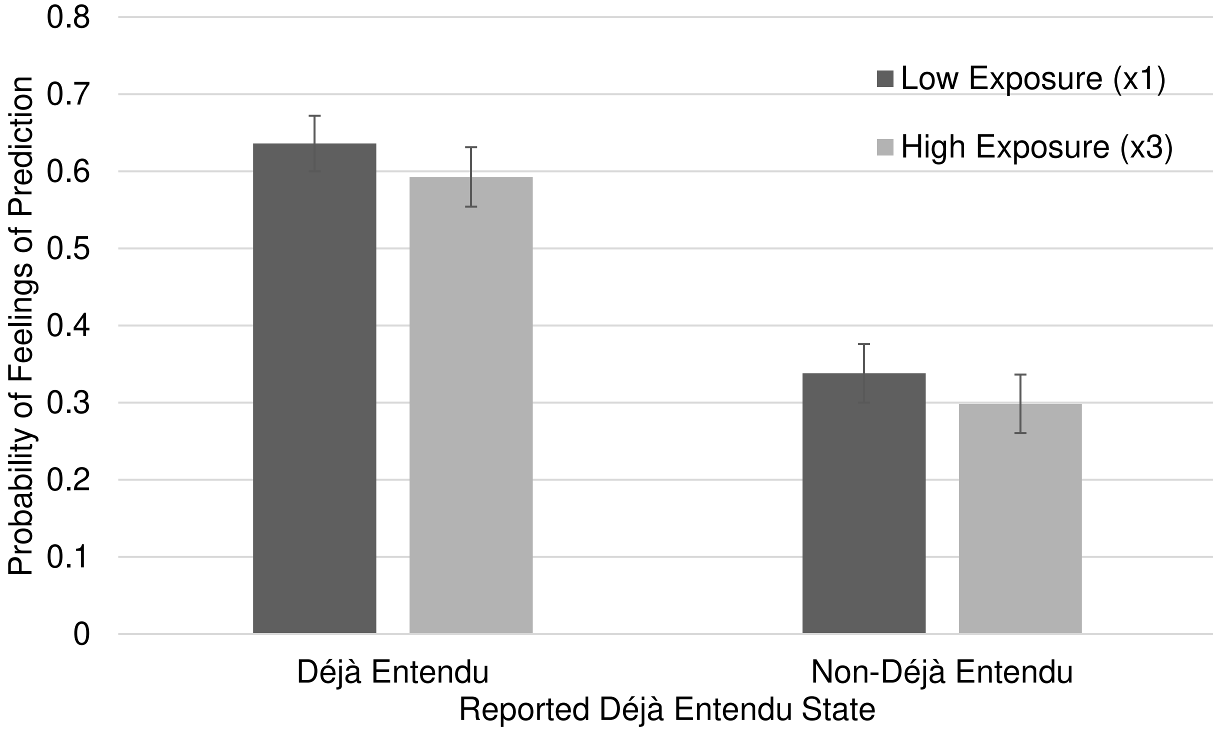

Figure 30. The probability of experiencing feelings of prediction for unaltered song clips corresponding to isolated tonal sequences based on déjà entendu state and exposure frequency condition.

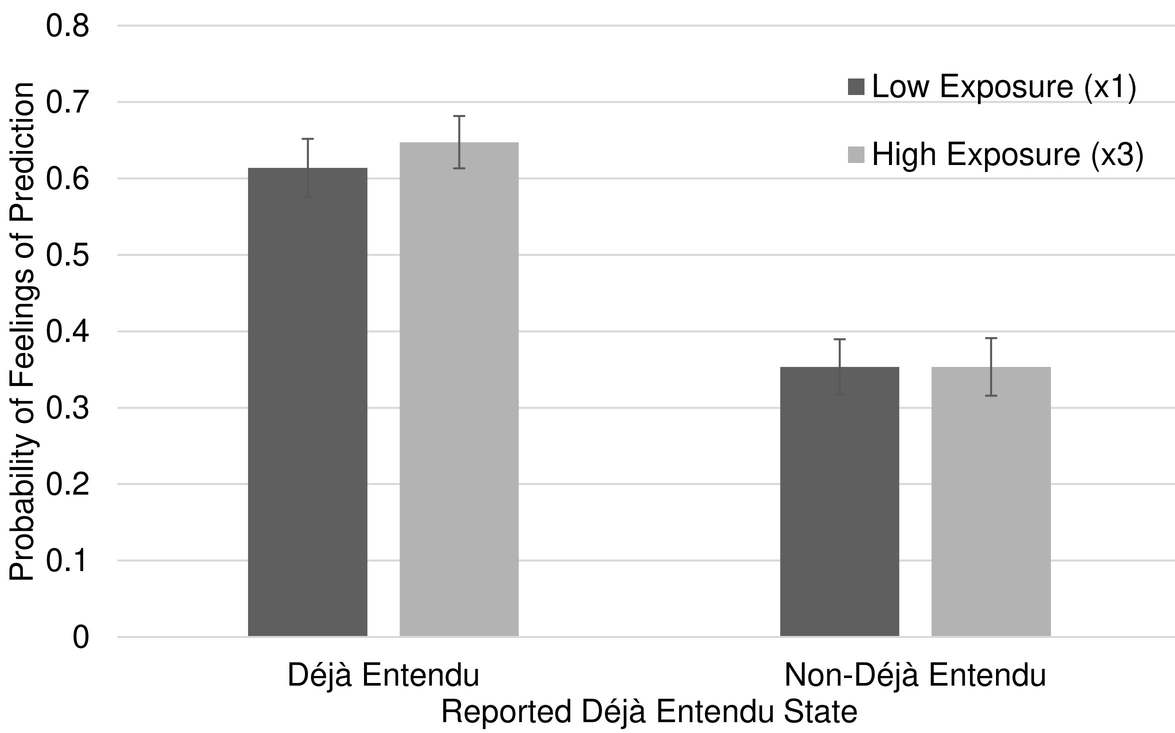

Figure 31. The probability of experiencing feelings of prediction for unaltered song clips corresponding to isolated rhythms based on déjà entendu state and exposure frequency condition.

A significant interaction was found, $F(2, 190) = 10.49$, $MSE = .03$, $p < .001$, $\eta_p^2 = .10$ (see Figure 32; note that 13 participants were lost from the analyses). There was a significant main effect of feature-type, $F(2, 190) = 22.84$, $MSE = .05$, $p < .001$, $\eta_p^2 = .19$. When participants had judged an unaltered song clip to be subjectively familiar, they were no more likely to experience feelings of prediction if the unaltered song clip contained a familiarized tonal sequence ($M = .59$, $SD = .33$) compared to if the unaltered song clip did not contain familiarized features ($M = .55$, $SD = .33$), $t(95) = 1.69$, $SE = .02$, $p = .093$.

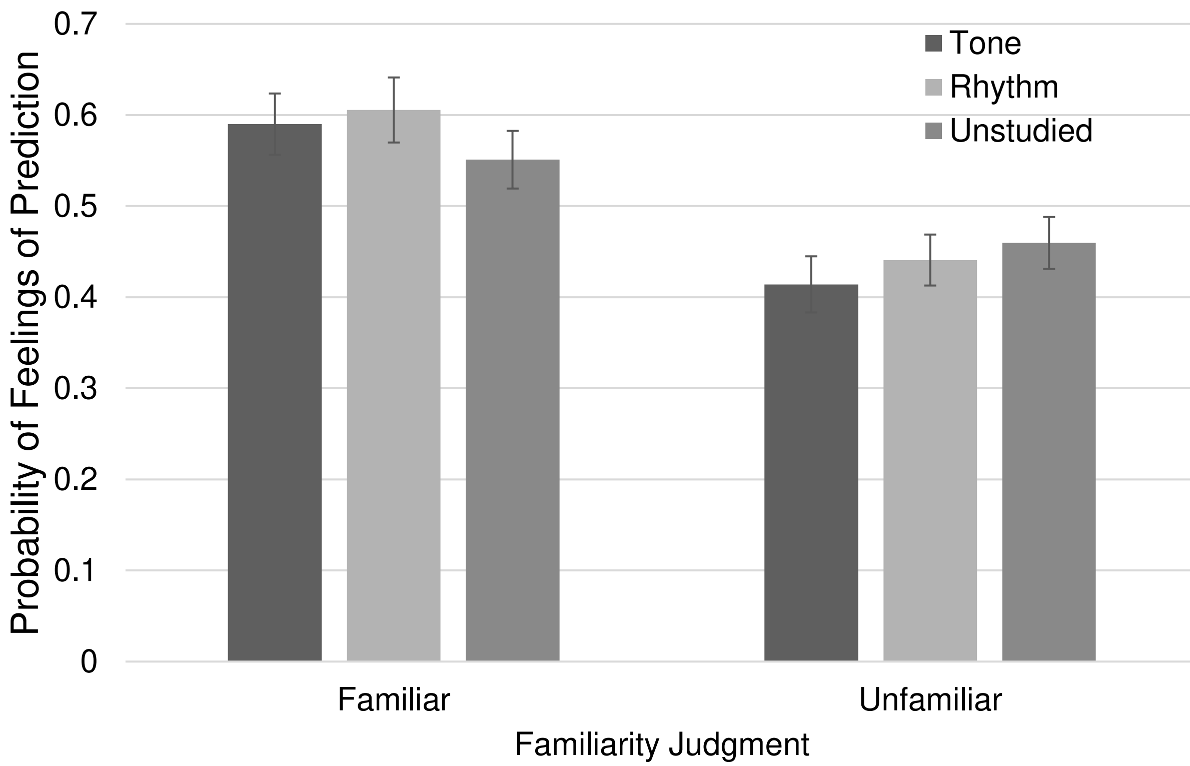

Figure 32. The probability of experiencing feelings of prediction based on the experimentally familiarized feature-type and participants' subjective familiarity judgments.

However, when participants had once again judged the unaltered song clip to be subjectively familiar, they were marginally more likely to experience feelings of prediction if the unaltered song clip contained a familiarized rhythm ($M = .61$, $SD = .35$)

compared to if it did not contain familiarized features, $t(95) = 2.02$, $SE = .03$, $p = .047$, $d = .18$. When examining trials in which the participants had judged the unaltered song clip to be subjectively unfamiliar, they were significantly more likely to experience feelings of prediction if the unaltered song clip contained a familiarized tonal sequence ($M = .42$, $SD = .30$) compared to if it did not contain familiarized features ($M = .46$, $SD = .28$), $t(95) = 2.78$, $SE = .02$, $p = .007$, $d = .14$.

The repeated-measures ANOVA also showed a significant main effect of familiarity judgment, $F(1, 95) = 4.40$, $MSE = .04$, $p = .039$, $\eta_p^2 = .04$. If the unaltered song clip did not contain familiarized features from study, participants were more likely to experience feelings of prediction if they had judged the unaltered song clip to be subjectively familiar ($M = .55$, $SD = .31$) compared to if they had judged it to be subjectively unfamiliar ($M = .46$, $SD = .28$), $t(95) = 2.78$, $SE = .03$, $p = .007$, $d = .30$. When participants heard an unaltered song clip that corresponded to an unidentified tonal sequence presented at study, they were more likely to experience feelings of prediction if they had judged the unaltered song clip as subjectively familiar ($M = .59$, $SD = .33$) than if they had judged the unaltered song clip to be subjectively unfamiliar ($M = .42$, $SD = .30$), $t(95) = 5.12$, $SE = .03$, $p < .001$, $d = .54$. If the unaltered song clip corresponded to an unidentified rhythm from study, participants were more likely to experience feelings of prediction if the unaltered song clip was judged as subjectively familiar ($M = .61$, $SD = .45$) compared to subjectively unfamiliar ($M = .45$, $SD = .27$), $t(95) = 4.79$, $SE = .03$, $p < .001$, $d = .41$.

Finally, to assess the effects of déjà entendu states and subjective familiarity ratings on participants' feelings of prediction, a 2 x 2 Déjà Entendu State (Déjà entendu, Non-déjà entendu) x Familiarity Judgment (Familiar, Unfamiliar) repeated-measures ANOVA was conducted. A significant main effect of déjà entendu state was found, $F(1, 75) = 90.51$, $MSE = .076$, $p < .001$, $\eta_p^2 = .55$ (see Figure 33; note that 32 participants were lost from the analyses). When participants had judged an unaltered song clip as subjectively familiar, they were more likely to experience feelings of prediction when also experiencing déjà entendu ($M = .64$, $SD = .31$) as opposed to non-déjà entendu ($M = .36$, $SD = .30$), $t(75) = 7.45$, $SE = .04$, $p < .001$, $d = 0.92$. When participants judged the unaltered song clips to be subjectively unfamiliar, a similar pattern emerged, such that they were more likely to experience feelings of prediction during déjà entendu states ($M = .65$, $SD = .30$) compared to non-déjà entendu states ($M = .33$, $SD = .27$), $t(75) = 8.58$, $SE = .04$, $p < .001$, $d = 1.13$.

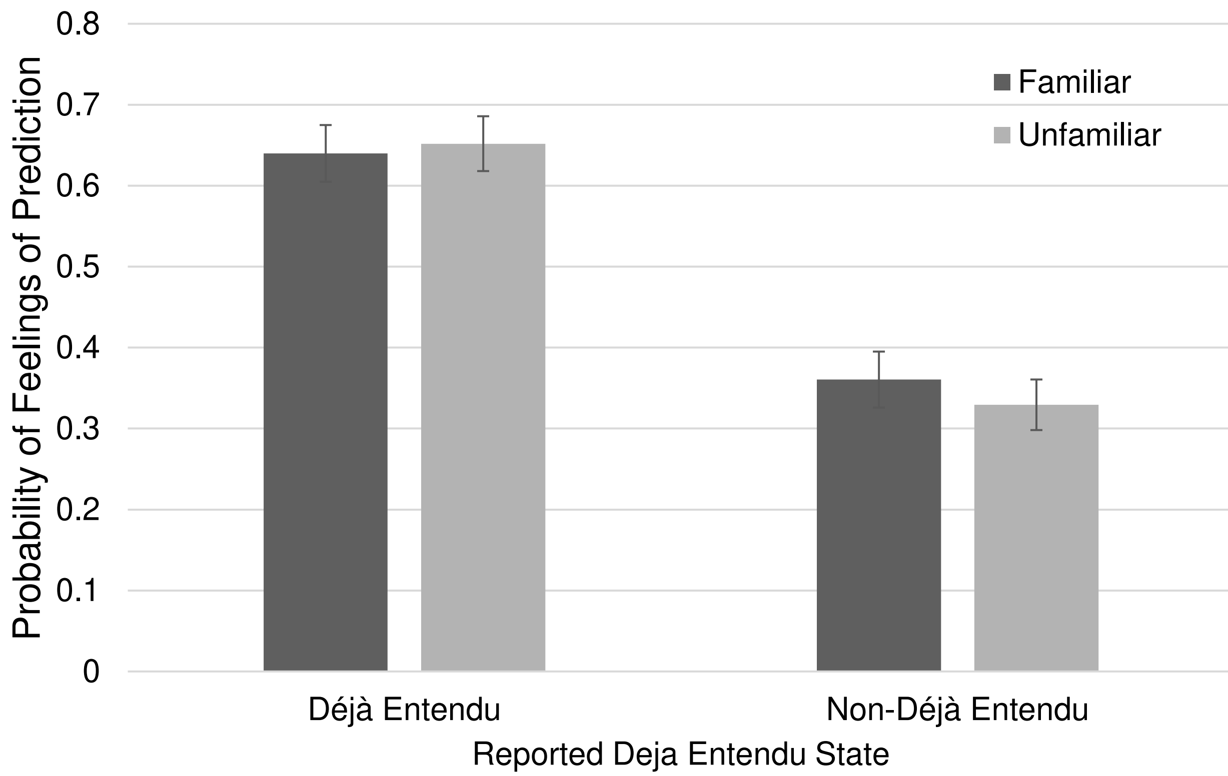

Figure 33. The probability of experiencing feelings of prediction based on the reported déjà entendu state and subjective familiarity judgment.

Unlike Experiment 3a, there was no significant main effect of familiarity judgment, $F(1, 75) = .13$, $MSE = .05$, $p = .719$. When participants were in a déjà entendu state, they were no more likely to experience feelings if prediction if they had judged the song to be subjectively familiar compared to subjectively unfamiliar, $t(75) = -.37$, $SE = .03$, $p = .713$. Additionally, when participants were in a non-déjà entendu state, there was no increase in the probability of reporting feelings of prediction when the song had been judged as subjectively familiar compared to subjectively unfamiliar, $t(75) = .92$, $SE = .03$, $p = .36$. There was also no significant interaction between déjà entendu state and familiarity judgment, $F(1, 75) = 1.14$, $MSE = .03$, $p = .290$, suggesting that the probability of participants experiencing feelings of prediction is primarily dependent upon their sense of déjà entendu and is not significantly affected by subjective familiarity judgments.

Chapter 7 - General Discussion

Since the inception of cognitive psychology as a scientific field of study, researchers have been examining the feeling of familiarity, both its origins and its role in memory processes and metacognitive states (Schwartz & Cleary, 2016). The current study was designed to further examine familiarity's function in regard to musical features and the metacognitive state of déjà entendu, which is the auditory version of déjà vu (Brown, 2004). The methodologies used in McNeely-White and Cleary (2019), in which *Piano Puzzlers* were used to examine real-world examples of how déjà entendu might occur, and that developed in Kostic and Cleary (2009) and then later adapted in McNeely-White and Cleary (invited revision), in which experimentally isolated musical features of rhythm and pitch were used to examine feelings of familiarity with novel song sequences during retrieval failure, were used in the current study to examine how increased exposure to features at study (i.e., No Exposure x0, Low Exposure x1, and High Exposure x3) lead to increased feelings of familiarity with songs during retrieval failure and also increased feelings of déjà entendu.

The logic of the current experiments' hypotheses and methodologies can be attributed to the current state of research examining familiarity and features held within memory traces. Methods have been developed over the years to study familiarity and its associated metacognitive states, such as the *butcher-on-the-bus* phenomenon (Mandler, 1980) and the déjà vu phenomenon (e.g., Cleary et al., 2012). While the latter metacognitive state has previously been associated in the public's eyes with supernatural and pseudoscience practices, the literature on familiarity and feature-matching has demonstrated that this metacognitive state and its subtypes are actually founded in memory processes, resulting from the individual failing to retrieve the origins of the features present in the current experience that are also held within memory traces of past events. Specifically, during retrieval failure, the features present in the current situation are still matched with features present in memory traces to produce a familiarity signal. Research on familiarity has suggested that the feeling arises due to the degree of match between the features held within the present cue and those that are held within memory traces (e.g., Clark & Gronlund, 1996). Upon being tested, all of the available features are combined to create a memory probe. The amount of overlap or match between the probe and the features held within the memory traces results in a familiarity signal, the strength of which varies as a function of feature-matching. When the overlap is high, the familiarity signal will be strong, signaling to the individual that the present stimulus was most likely previously encountered, as memory is an adaptive mechanism.

While theorists have developed elaborate memory models for memory traces, features, and familiarity signals (e.g., Hintzman, 1988; Clark & Gronlund, 1996; Cox & Shiffrin, 2017), there has only been a recent shift towards experimentally examining what features are held within memory traces and how these features contribute to the familiarity signal. As previously discussed, the RWI paradigm has been used in probing memory traces to observe that features such as letters, (Cleary, 2002), graphemes (Cleary, 2004; Ryals & Cleary, 2012) , geons (Cleary, Langley, & Seiler, 2004), phonemes (Cleary, Winfield, & Kostic, 2007), and rhythm and tonal sequences (Kostic & Cleary, 2009; McNeely-White & Cleary, invited revision) are held within memory traces.

Repeatedly, researchers have used the RWI paradigm to examine familiarity during retrieval failure, further contributing to the knowledge of features and familiarity-detection.

From this research on familiarity-based recognition and types of features that are held within memory traces, we have come to better understand metacognitive states that offer insight into memory during retrieval failure, such as the *butcher-on-the-bus* phenomenon (Mandler, 1980) and the tip-of-the-tongue experience (Schwartz & Cleary, 2016). Of particular interest to the current study is the metacognitive state of déjà vu. As previously discussed, déjà vu is thought to occur due to the individual having previously encountered a spatially similar scene but failing to recall this instance (e.g., Cleary et al., 2012; Cleary et al., 2018). The features held within the memory trace are matching with the current environment's cues, yet the individual fails to recall the specifics of the previously encountered scene, or even that there was a similar scene, thus creating a strange juxtaposition between old and new features. As research on this specific metacognitive state has continued, we now have a better understanding of the déjà vu phenomenon, which was once thought to be beyond the realm of scientific study (see Schacter, 2001).

The current study was designed to not only examine musical features and how they are held within memory traces, but to also examine whether embedding familiarized musical features into novel song sequences might create an analogous experience to the déjà vu phenomenon, but in the auditory realm – the sense of déjà entendu. Preliminary research on this subject has been conducted, establishing that déjà entendu can be scientifically studied and that the mechanism may be similar to that of déjà vu in that déjà entendu was more likely to occur when the *Piano Puzzler* was judged as familiar and contained familiarized musical features as opposed to no familiarized musical features (McNeely-White & Cleary, 2019). However, while this was a necessary step towards understanding the déjà entendu phenomenon and the nature of musical features, the original study lacked the experimental control in its stimuli creation, as the *Piano Puzzlers* were created by a music composer with the intent to entertain people, not scientifically study their memory processes. Therefore, the current study expanded on the methodology used by McNeely-White and Cleary by increasing exposure to the original features at study that would later be present in *Piano Puzzlers*. Additionally, in Experiments 2, 3a, and 3b, the specific feature-familiarization technique developed by Kostic and Cleary (2009) was utilized to examine how precise feature familiarization might lead to déjà entendu. To further boost the probability of experiencing déjà entendu, increased exposure to features at study was incorporated, as McNeely-White and Cleary (invited revision) demonstrated that this method does indeed increase subjective familiarity with song sequences.

Additional points of interest to the current study concern illusory feelings of prediction during déjà entendu. As demonstrated by Cleary and Claxton (2018), in the moment of experiencing déjà vu, participants erroneously believe that they can predict the outcome of an event, despite showing at chance prediction accuracy. Furthermore, Cleary, Huebert, McNeely-White, and Spahr (2019) demonstrated that even during situations experimentally designed for predictions to be impossible (i.e., a counterfeit study list), participants exhibited high feelings of prediction during instances of déjà vu. If déjà entendu is similar in its origins to déjà vu, then perhaps it might also lead to illusory feelings of prediction. Experiments 3a and 3b investigated this question and found evidence that déjà entendu is associated with illusory feelings of prediction. Moreover, as with déjà vu, familiarity appears to be involved.

The RWI Phenomenon

The RWI effect, in which a participant is able to discriminate between studied and unstudied stimuli based on familiarity alone, has been demonstrated in previous studies examining features and musical stimuli (e.g., Kostic & Cleary, 2009; McNeely-White & Cleary, 2019; McNeely-White & Cleary, invited revision). All of the current experiments also found this basic effect, using both *Piano Puzzlers* (Experiment 1) and unaltered well-known children's songs, pop songs, and rock songs (Experiments 2, 3a, and 3b). Of interest to the current study, though, was whether increasing exposure to features at study had a significant effect on participants' subsequent familiarity judgments at test. Focusing on Experiment 1, which used *Piano Puzzlers* at test, the increase in exposure to the *Piano Puzzlers's* original song format at study partially had an effect on familiarity judgments. The increase in exposure to the original song's features only increased the probability of judging a song as familiar when the features were exposed three times at study compared to when there were no features exposed at study. The null result of *Piano Puzzlers* which corresponded to an original song presented once at study not significantly increasing the probability of judging a song as familiar compared to *Piano Puzzlers* which did not correspond to an original song presented at study is inconsistent with the results of McNeely-White and Cleary (2019) who also used *Piano Puzzlers* to find that participants are more likely to judge a *Piano Puzzler* as familiar if it corresponded to an original song at study compared to if it did not. However, the pattern of results between the current findings and that of McNeely-White and Cleary seem to be similar in that the RWI effect is dependent upon déjà entendu reports. The lack of added benefit of repeated exposure to a *Piano Puzzler's* original features may be due to the features themselves not being an exact match.

Turning to the experiments that used the isolated feature familiarization process, the effects of exposure were replicated across the three experiments. As exposure to the isolated features at study increased, the probability of subsequently judging a test song as familiar also increased. When familiarizing isolated tonal sequences, the added exposure instances significantly increased the probability of judging a song as familiar compared to single exposure condition. Somewhat inconsistent with the findings of McNeely-White and Cleary (invited revision), though, are the current experiments' results of familiarizing isolated rhythms at study and how exposure affects the probability of judging a song as familiar. Whereas McNeely-White and Cleary found that the probabilities of judging a song as familiar differed when the song contained a familiarized rhythm presented once compared to three times at study, the same effect was not found in the current experiments. Indeed, we replicated the finding that songs containing a familiarized rhythm presented once at study were more likely to be judged as subjectively familiar compared to songs which did not contain a familiarized rhythm, but the increased probability of judging a song as familiar if it contained a rhythm familiarized three times compared to only one time was not found across three experiments.

As previously mentioned, there was an insignificant pattern found in Experiment 2 such that there were no differences in the probability of judging a song as familiar based on its exposure condition. This may have been due to participants only being asked to provide a familiarity rating if they had judged the song clip to be subjectively familiar. To complete the experiment faster, participants may have intentionally answered “No” to song clips that in reality did feel subjectively familiar so that they would not have to answer the additional question concerning the familiarity rating. This may have affected the results. However, upon comparing the probabilities of judging a song clip as familiar between Experiments 2 and 3a, the latter of which only asked for a familiarity judgment, there was no significant difference. Participants were just as likely to judge a song clip containing familiarized features as subjectively familiar in Experiment 2 (M = .38, SD = .20) and Experiment 3a (M = .39, SD = .20), $t(217)$ -.41, SE = .03, p = .687. There was also no difference for song clips that did not contain familiarized features between Experiments 2 (M = .30, SD = .20) and 3a (M = .33, SD = .21), $t(217)$ = -1.35, SE = .03, p = .179. This rules out the possibility that the familiarity judgments in Experiment 2 were not reflective of what participants actually sensed.

Taken together, these findings suggest two things in regard to memory traces and the nature of features in the familiarity signal summation. First, as suggested by McNeely-White and Cleary (invited revision), increasing the number of exposure instances to isolated features further increases the strength of the familiarity signal. This principle was first explored by Ryals and Cleary (2012) in their use of graphemically similar words, as increasing the level of feature overlap increased the probability of judging a word as subjectively familiar. Similarly, in our study, we increased the level of feature overlap by exposing participants to the feature multiple times. The demonstrated increase in the probability of judging a song as familiar due to increased exposure suggests that the familiarity summation process takes exposure of the feature into consideration. These experimental findings provide evidence that exposure does indeed carry influence on the familiarity signal, something that has not been previously empirically demonstrated.

Second, these findings suggest that perhaps the features of tone and rhythm do carry different weights within the memory trace. In their study examining familiarized musical feature isolation at test, Kostic and Cleary (2009) found that, when comparing subjective familiarity ratings given to isolated features that either came from studied songs or unstudied songs, there were larger effect sizes for tonal sequences than rhythms. These early findings suggest that tonal information possibly carries more weight in the computation of the familiarity signal than rhythmic information. While McNeely-White and Cleary (invited revision) found that there are no differences in the probability of judging a song as familiar if it contained a familiarized tonal sequence or a familiarized rhythm (there was only increased familiarity when *both* features were familiarized for a single song), our findings on exposure and feature-type suggest that perhaps there are differences, but only when the feature was exposed multiple times. There may be a non-linear relationship present, such that tonal information is more heavily weighted in the memory trace and familiarity signal when there are multiple instances of encountering the tonal feature, as seen in the differences in the probability of judging a song as familiar when the feature was presented three times. For example, the 2 x 2 Feature-Type (Tone, Rhythm) x Exposure Frequency (Low Exposure x1, High Exposure x3) ANOVAs on the probability of judging a song as familiar in Experiments 2, 3a, and 3b revealed significant main effects of Feature-Type, such that participants were more likely to judge a song as familiar if it contained a familiarized tonal sequence compared to a familiarized rhythm. This difference becomes more extreme when looking at songs containing features familiarized three times at study. Taken together, these findings suggest that there are indeed differences in the weight of individual features in the familiarly summation process, particularly when the feature has additional representations in the memory trace, further suggesting that there is a non-linear relationship at play. Future studies should develop *a prior* hypotheses to test this suggestion, either using the specific features of rhythm and tone or perhaps using different features that have previously been demonstrated to be held within memory traces, such as semantics (Cleary, Ryals, & Wagner, 2015), phonemes (Cleary, Winfield, & Kostic, 2007), or geons (Cleary, Langley, & Seiler, 2004).

The Déjà Entendu Phenomenon

Research on the déjà vu phenomenon has increased in the past decade, providing us with a better understanding of its mechanisms and implications for memory processes. With the growing acceptance of déjà vu as scientifically accessible topic of study, this has allowed for additional research on its subtypes, such as the déjà entendu phenomenon. In addition to examining features and their role in the familiarity signal, another purpose of the current study was to examine how the metacognitive state of déjà entendu may originate from the failure to recognize previously familiarized features presented in a novel context. In research on the déjà vu phenomenon, the probability of experiencing déjà vu is higher when the test stimulus contained familiarized spatial features presented at study (e.g., Cleary et al., 2012; Cleary & Claxton, 2018; Cleary et al., 2018). In an analogous situation, in which musical features familiarized at study were later presented in a novel test cue, similar results were found in the current experiments in relation to déjà entendu. Across experiments, participants were significantly more likely to experience déjà entendu for songs that contained familiarized features, for both *Piano Puzzlers* (Experiment 1) and unaltered well-known children's songs, pop songs, and rock songs (Experiments 2, 3a, and 3b).

When factoring in the level of exposure to the studied features, though, the findings are mixed. In Experiment 1, in which *Piano Puzzlers* were used, there was only a marginally significant effect of exposure on the probability of experiencing déjà entendu when comparing *Piano Puzzlers* that corresponded to songs containing familiarized features exposed three times versus none. This may perhaps be attributed to the fact that the level of feature overlap between *Piano Puzzlers* and the original versions of the songs used at study was not precise. The purpose of using precise feature-familiarization techniques in Experiments 2, 3a, and 3b was to alleviate this lack of overlap. However, these findings are mixed, with Experiment 2 only showing a significant effect for songs containing features familiarized three times compared to no familiarized features, and Experiment 3a showing significant effects for the No Exposure (x0) x Low Exposure (x1) and No Exposure x High Exposure comparisons, but not for the Low Exposure (x1) x High Exposure (x3) comparison. Additionally, in Experiment 3b, there were significant effects for the No Exposure (x0) x High Exposure (x3) and Low Exposure (x1) x High Exposure (x3) comparisons, but not the No Exposure (x0) x Low Exposure (x1) comparison. A potential reason for these mixed results may be that these comparisons were collapsing across feature-type. Upon further analysis, unaltered song clips containing familiarized tonal sequences almost consistently across experiments showed that participants were significantly or marginally significantly more likely to experience déjà entendu as exposure to the tonal sequences increased (In Experiment 3a, the comparison between No Exposure and Low Exposure had a *p*-value of .103). For unaltered song clips containing familiarized rhythms, the results from Experiments 2, 3a, and 3b suggest that participants are not often likely to experience déjà entendu [In Experiment 2, there was a marginally significant difference in the No Exposure (x0) x High Exposure (x3) comparison, and marginally significant differences in Experiment 3a for the No Exposure (x0) x Low Exposure (x1) comparison and No Exposure (x0) x High Exposure (x3) comparison]. These findings suggest that perhaps déjà entendu is more likely to occur when exposure to the isolated features was high and that familiarized tonal information, which inherently “richer” than rhythmic information, is more likely to elicit this phenomenon.

Illusory Feelings of Prediction

Another aim of the current study was to examine whether participants experienced illusory feelings of prediction when aspects of the unaltered song clip had been previously familiarized. Research examining déjà vu has demonstrated that participants exhibit illusory feelings of prediction in that they feel as if they can predict the outcome of an event yet show accuracy that is at chance (e.g., Cleary & Claxton, 2018). Similar findings were seen in the current experiments. In Experiment 3a, participants were more likely to report experiencing feelings of prediction for the contour of a song if they also reported being in a déjà entendu state compared to when they were in a non-déjà entendu state. However, when examining their accuracy, as there was the possibility of correctly predicting the proceeding note’s contour, participants were at chance, suggesting that these feelings were primarily illusory. When further examining this illusory feeling in Experiment 3b, participants again demonstrated a relationship between déjà entendu and feelings of prediction, in that they were more likely to report feelings of prediction during déjà entendu reports. However, the event that they were predicting (i.e., whether the proceeding note would play out of the left or right speaker) had been experimentally randomized so that there was no true answer. Despite this, participants demonstrated feelings of prediction during déjà entendu.

Although examining the influence of exposure frequency and the role of subjective familiarity did not lead to a consistent conclusion across the two experiments, as neither increased exposure nor subjective familiarity predicted an increase in the probability of experiencing feelings of prediction, the role of déjà entendu is consistent. Similar to other metacognitive states, such as déjà vu and tip-of-the-tongue, déjà entendu biases participants to have increased confidence or stronger beliefs about their abilities. Despite participants showing no predictive ability, they consistently reported feeling as if they could predict an event during déjà entendu. This phenomenon may be similar to that of the tip-of-the-tongue bias in that participants experiencing this metacognitive state show increased risk-taking behaviors and feel more confident in their abilities than is appropriate (e.g., Cleary, 2019; Cleary, Huebert, & McNeely-White, 2020). As argued by Schacter, Addis, and Buckner (2007), memory's primary adaptive function is to apply previous experiences to current events in order to predict the outcome of an action or decision. It may be that metacognitive states, such as déjà entendu, are signaling to the individual that something exists within memory that overlaps with the current experience. Participants may erroneously interpret this signal as reason to believe that they have reason to believe that there is a logical outcome of the current event held within memory, thus having increased confidence in their predictions. However, as metacognitive states such as déjà entendu occur because the participant fails to recall the original scenario in which they encountered these features, the outcome of the initial event is not necessarily accessible, thus creating a disconnect between participant's feelings and their actual capabilities.

Conclusions

The current experiments investigated familiarity processes and how musical features are held within memory traces to later be used in the recognition process, specifically through the use of music. As familiarity is associated with the metacognitive state of déjà vu, the potential role of familiarity in déjà entendu was also examined. When exposed to song clips at test, such as in the form of *Piano Puzzlers* (Experiment 1) or children's nursery songs (Experiments 2, 3a, and 3b) that contained familiarized features, participants were significantly more likely to experience feelings of familiarity despite experiencing retrieval failure. Additionally, participants reported feeling a sense of déjà entendu when the test song clip had experimentally familiarized elements, which subsequently lead to illusory feelings of prediction. Overall, the results further support that the musical features of rhythm and pitch are separable features held within memory traces, and that subjective familiarity plays a role in déjà entendu.

References

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review,* 94, 115–147.

Brown, A. S. (2003). A review of the déjà vu experience. *Psychological Bulletin, 129,* 394–413.

Brown, A. S. (2004). *The déjà vu experience*. New York, Psychology Press.

Bruce Adolphe's Piano Puzzlers (2018, August 29). Retrieved from: https://www.yourclassical.org/programs/performance-today/topic/piano-puzzler

Clark, S. E., & Gronlund, S. D. (1996). Global matching models of recognition memory: How the models match the data. *Psychonomic Bulletin & Review, 3*(1), 37–60.

Cleary, A. M. (2002). Recognition with and without identification: Dissociative effects of meaningful encoding. *Memory & Cognition*, 30, 758-767.

Cleary, A. M. (2004). Orthography, phonology, and meaning: Word features that give rise to feelings of familiarity. *Psychonomic Bulletin & Review, 3*(11), 37–60. doi:10.3758/BF03196593

Cleary, A. M. (2008). Recognition memory, familiarity, and déjà vu experiences. *Current Directions in Psychological Science, 17*, 353–357. doi: 10.1111/j.1467-8721.2008.00605.x

Cleary, A. M. (2014). The sense of recognition during retrieval failure: Implications for the nature of memory traces. *Psychology of Learning and Motivation, 60*, 77–112.

Cleary, A. M. (2019). The biasing nature of the tip-of-the-tongue experience: When decisions bask in the glow of the tip-of-the-tongue state. *Journal of Experimental Psychology: General, 148*, 1178-1191.

Cleary, A. M., Brown, A. S., Sawyer, B. D., Nomi, J. S., Ajoku, A. C., & Ryals, A. J. (2012). Familiarity from the configuration of objects in 3-dimensional space and its relation to déjà vu: A virtual reality investigation. *Consciousness and cognition, 21*, 969–975.

Cleary, A. M., & Claxton, A. B. (2018). Déjà vu: An illusion of prediction. *Psychological Science, 29,* 635–644. doi:10.1177/0956797617743018

Cleary, A. M., & Greene, R. L. (2000). Recognition without identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1063–1069.

Cleary, A. M., & Greene, R. L. (2001). Memory for unidentified items: Evidence for the use of letter information in familiarity processes. *Memory & Cognition*, 29, 540-545.

Cleary, A. M., Huebert, A. M., & McNeely-White, K. L. (2020). The tip-of-the-tongue state bias permeates unrelated concurrent decisions and behavior. *Memory & Cognition*.

Cleary, A. M., Huebert, A. M., McNeely-White, K. L., & Spahr, K. S. (2019). A postdictive bias associated with déjà vu. *Psychonomic Bulletin & Review*. doi:10.3758/s13423-019-01578-w

Cleary, A. M., Langley, M. M., & Seiler, K. R. (2004). Recognition without picture identification: Geons as components of the pictorial memory trace. *Psychonomic Bulletin & Review, 11*, 903–908.

Cleary, A. M., McNeely-White, K. L., Huebert, A. M., & Claxton, A. B. (2018). Déjà vu and the feeling of prediction during retrieval failure: an association with familiarity strength. *Memory*. doi:10.1080/09658211.2018.1503686

Cleary, A. M., & Reyes, N. L. (2009). Scene recognition without identification. *Acta Psychologica, 131*(1), 53–62. doi:10.1016/j.actpsy.2009.02.006

Cleary, A. M., Ryals, A. J., & Nomi, J. S. (2009). Can déjà vu result from similarity to a prior experience? Support for the similarity hypothesis of déjà vu. *Psychonomic Bulletin & Review, 16*, 1082–1088. doi:10.3758/PBR.16.6.1082

Cleary, A. M., Ryals, A. J., & Wagner, S. R. (2015). Recognition during recall failure: Semantic feature matching as a mechanism for recognition of semantic cues when recall fails. *Memory & Cognition, 44*, 50–62.

Cleary, A. M., Winfield, M. M., & Kostic, B. (2007). Auditory recognition without identification. *Memory & Cognition, 35*, 1869–1877.

Cox, G. E., & Shiffrin, R. M. (2017). A dynamic approach to recognition memory. *Psychological Review, 124*, 795–860. doi:10.1037/rev0000076

Dowling, W. J., & Harwood, D. L. (1986). *Music Cognition*. Orlando, Academic Press.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*, 28, 1–11.

Goldstein, D. G., & Gigerenzer, G. (2002). Models of ecological rationality: The recognition heuristic. *Psychological Review, 109*(1), 75–90. doi: 10.1037//0033-295X.109.1.75

Hintzman, D. L. (1988). Judgments of frequency and recognition memory in a multiple-trace memory model. *Psychological Review, 95*, 528-551.

Huran, D. (2006). *Sweet Anticipation: music and the psychology of Expectation.* Massachusetts, MIT Press.

Kostic, B., Booth, S. E., & Cleary, A. M. (2015). The role of analogy in reports of presque vu: Does reporting the presque vu state signal the near retrieval of a source analogy? *Journal of Cognitive Psychology, 27,* 739–754. doi:10.1080/20445911.2015.1031792

Kostic, B., & Cleary, A. M. (2009). Song recognition without identification: When people cannot “name that tune" but can recognize it as familiar. *Journal of Experimental Psychology: General, 138*(1), 146–159.

Kostic, B., Cleary, A. M., Severin, K., & Miller, S. W. (2010). Detecting analogical resemblance without retrieving the source analogy. *Psychonomic Bulletin Review, 17,* 405–411. doi:10.3758/PBR.17.3.405.

Krumhansl, C. L. (2000). Rhythm and pitch in music cognition. *Psychological Bulletin, 126,* 159–179.

Mandler, G. (1980). Recognizing: the judgement of previous occurrence. *Psychological Review, 87,* 252–271.

Mandler, G. (1991). Your face looks familiar but I can’t remember your name: A review of dual process theory. In W. E. Hockley & S. Lewandowsky (Eds.). Relating Theory and Data: Essays on Human Memory in Honor of Bennet B. Murdock. Hillsdale, New Jersey: Lawrence Erlbaum Associates. Pp. 207–225.

Mandler, G. (2008). Familiarity breeds attempts: A critical review of dual-process theories of recognition. *Perspectives on Psychological Science, 3,* 390–399.

McNeely-White, K. L., & Cleary, A. M. (2019). Music recognition without identification and its relation to déjà entendu: A study using “Piano Puzzlers.” *New Ideas in Psychology*, 55, 50–57.

McNeely-White, K. L., & Cleary, A. M. (invited revision). How musical features combine across memory traces to increase familiarity with the whole in which they are embedded: Support for global matching in musical familiarity. *Journal of Memory and Language.*

Neppe, V. M. (1983). *The psychology of déjà vu: Have I been here before?* Johannesburg: Witwatersrand University Press.

Pavio, A. (1986). *Mental representations: A dual-coding approach.* New York: Oxford University Press.

Pavio, A. (1991). Dual-coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45,* 255–287.

Pearce, M. T., & Wiggins, G. A. (2005). Expectations in melody: the influence of context and learning. *Music Perception: An Interdisciplinary Journal, 23,* 377–405.

Peynircioğlu, Z. F. (1990). A feeling-of-recognition without identification. *Journal of Memory and Language, 29*, 493-500

Ryals, A. J., & Cleary, A. M. (2012). The recognition without cued recall phenomenon: Support for a feature-matching theory over a partial recollection account. *Journal of Memory and Language, 66,* 747–762.

Schacter, D. L. (2001). *The seven deadly sins of memory: How the mind forgets and remembers*. New York: Houghton Mifflin.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: The prospective brain. *Nature Reviews Neuroscience*, *8*, 657–661.

Schwartz, B. L., & Cleary, A. M. (2016). Tip-of-the-tongue states, déjà vu experiences, and other odd metacognitive experiences. In J. Dunlosky & S. K. Tauber (Eds.), The Oxford Handbook of Metamemory. Oxford University Press. (pp. 95–108).

Vlasov, P. N., Chervyakov, A. V., Gnezditskii, V. V. (2013). Déjà vu phenomenon-related EEG pattern. Case report. *Epilepsy & Behavior Case Reports, 1,* 136–141. doi:10.1016/j.ebcr.2013.08.001

Wild, E. (2005). Déjà vu in neurology. *Journal of Neurology, 252*, 1–7. doi:10.1007/s00415-005-0677-3

Yonelinas, A. P. (2002). The nature of recollection and familiarity: a review of 30 years of research. *Journal of Memory and Language, 46,* 441–517.

Appendix A

In this experiment, you will hear a list of song. This is the study segment of the experiment. As you listen to the songs, you should try your best to identify and remember each of them. When the study segment is over, you will be presented with a memory test.

During the test segment you will hear another list of songs. Some of the songs may be similar to those that you heard during the study phase, but will be played in a different style. After each test song clip is presented, you will be asked whether the song prompts you to feel a sense of déjà entendu. Déjà entendu is the feeling of having heard something before despite knowing that it is completely new. You will then be asked to judge how familiar it seems to you, with the idea being that if you had just heard a very similar song on the study list, the current song will seem more familiar. You will then be asked to identify the song, if you can. There will be 5 short study-test sessions altogether for this experiment. If need be, you can adjust the volume on the speaker dial; turning to the left will turn the volume down; turning to the right will turn the volume up.

Appendix B

In this experiment, you will hear a list of song clips containing isolated song features like rhythm and tone. This is the study segment of the experiment. As you listen to the song features you should try your best to identify and remember each of them. When the study segment is over, you will be presented with a memory test.

During the test segment you will hear full song clips. Half of the song clips will have had isolated features (rhythm or tone) presented at study and half will not have. After each test song clip is presented, you will be asked whether you are experiencing déjà entendu, the feeling of having heard something before despite knowing that you have not heard it before. Afterwards, you will be asked to judge how familiar the song clip seems to you, with the idea being that if you had just heard some if its features on the study list, the song features will seem more familiar to you. You will then be asked to identify the song, if you can.

Appendix C

In this experiment, you will hear a list of song clips containing isolated song features like rhythm and tone. This is the study segment of the experiment. As you listen to the song features you should try your best to identify and remember each of them. When the study segment is over, you will be presented with a memory test.

During the test segment you will hear full song clips. Half of the song clips will have had isolated features (rhythm or tone) presented at study and half will not have. After each test song clip is presented, you will be asked whether you are experiencing déjà entendu, the feeling of having heard something before despite knowing that you have not heard it before. Afterwards, you will be asked to judge how familiar the song clip seems to you, with the idea being that if you had just heard some if its features on the study list, the song features will seem more familiar to you. Additionally, you will be asked whether you feel you can predict whether the next note is going to go up or down in pitch. You will then be asked to make a prediction about whether the song will go up or down in pitch. Finally, you will then be asked to identify the song, if you can.