MATCH THE MELODIES: HOW DO MUSICAL ABILITY AND TRAINING FRQUENCY AFFECT TRANSLATION-AMBIGUOUS WORD LEARNING?

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Eleanna Melcher
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This thesis was presented

by

Eleanna Melcher

It was defended on

April 15, 2019

and approved by

Marc Coutanche, University of Pittsburgh, Department of Psychology

L. Robert Slevc, University of Maryland, Department of Psychology

Gabriela Terrazas-Duarte, University of Pittsburgh

Thesis Advisor: Natasha Tokowicz, University of Pittsburgh, Department of Psychology

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This study investigated how musical ability/experience and training frequency for translation-ambiguous words affects learning. Native English speakers with no prior exposure to Dutch or German were taught German vocabulary words that were either unambiguous (one English translation) or ambiguous (two translations). Translation-ambiguous words were counterbalanced into two conditions, standard and overtrained (with the second translation being presented either three times or six times respectively). The testing assessments were a translation recognition task in which participants indicated whether pairs of words were translations and a free recall task. Participants also completed four indices of musical ability and experience: comparing rhythmic and melodic phrases, listening to and singing short melodies, and reflecting on their subjective musical experiences. This study provides further support for the challenges of learning translation-ambiguous words. It presents a potential method by which to alleviate the translation-ambiguity disadvantage, specifically by overtraining the second translation of ambiguous words. Furthermore, it illustrates the presence of an interaction between musical

ability and lexical learning, such that greater musical ability scores led to better learning outcomes.

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1.0 INTRODUCTION

One of the most striking abilities of humans is our communicative power. Through language we are able to write, read, sign, and speak to one another. However, our ability to communicate is limited by the over 6,000 languages in the world. A means by which we overcome this barrier, is to learn languages other than our native tongue.

In some cases when learning another language, words can be directly translated such that a word in the first language (L1) is roughly equivalent to a word in the second language (L2). However, as illustrated by the Revised Hierarchical Model for Translation Ambiguity (Eddington & Tokowicz, 2013; see also Kroll & Tokowicz, 2001), not all words have this one-to-one mapping—many have more than one translation into another language; these are called translation-ambiguous words. Examples of such words are the German word Boden, which translates to floor and ground, or the German word Folge, which translates to episode and result/consequence. As evidenced by these two examples of translation-ambiguous words, the two translations can be very close in meaning or quite disparate. To measure this aspect of the translations, a measure called translation semantic variability (TSV) was developed (Bracken, Degani, Eddington, Tokowicz, 2017). TSV is an important measure to examine, because words with translations having higher TSV scores, indicating that the translations are more semantically similar, are recognized more quickly and accurately (Bracken et al., 2017).

Translation-ambiguous words are more challenging to learn, recognize, and produce than translation-unambiguous words (see review in Tokowicz, 2014); this is referred to as the translation-ambiguity disadvantage. In comparison to words that have only one translation, translation-ambiguous words are produced more slowly and with lower accuracy (Degani & Tokowicz, 2010). However, Degani, Tseng, and Tokowicz (2014), did find that translation-ambiguous words are *recalled* more accurately than unambiguous words. Therefore, in analyses of translation recognition and translation recall, seemingly contradictory evidence may be found. This difference is thought to be caused by the 'greater noticeability' of translation-ambiguous words owing to the greater challenge inherent in learning them; a similar effect is sometimes found for low-frequency words (see e.g., DeLosh & McDaniel, 1996).

When learning translation-ambiguous words, it is advantageous to learn both translations at the same time, as opposed to learning one first, and then learning the other later (Degani, Tseng, & Tokowicz, 2014). This finding is contrasted by traditional classroom-based learning. Many people have had the experience of learning a foreign language in school. Such language classes are often organized thematically or semantically, meaning that the vocabulary learning is limited to words within the theme of the chapter (e.g., things at the beach, school subjects, colors, etc.). Even if a word within one of these sets has another translation, it is most often not taught or mentioned until later. Previous laboratory research suggests that the result of teaching the second translation separately, would be an ambiguity disadvantage. What this implies is that the translation ambiguous word pair learned first would be learned better, whereas the translation learned second would exhibit a decreased learning outcome (Degani, et al., 2014). This is thought to be caused by the fact that when the translation-ambiguous pairs are taught together, a one-to-many mapping can be formed immediately, as opposed to having to learn a one-to-one mapping and later having to revise it (Degani et al., 2014). With the ambiguity-disadvantage in mind, what additional instructional methods can be employed to alleviate the difficulties of learning translation-ambiguous words?

Recent research has attempted to use a placeholder teaching method to minimize the translation-ambiguity disadvantage. This method teaches participants a word and one of its translations, while also indicating using a blank line that the word has a second translation that will be taught later. This training manipulation only benefited participants who had cognitive advantages relative to other participants, specifically larger L1 vocabularies as measured by the Peabody Picture Vocabulary Test IV (Dunn, Dunn, & Pearson Assessments, 2007), better ability to ignore task-irrelevant information as measured using the Stroop task (Stroop, 1935), and higher proactive control as measured with the AX-CPT task (Ophir, Nass, & Wagner, 2009). These findings indicate that these participants may have had a greater ability to temporarily incorporate the placeholder into their L1 to L2 lexical mappings for the translation-ambiguous words, and therefore make better use of the metalinguistic information provided by the placeholder (Terrazas, 2018).

Similar to the placeholder manipulation of Terrazas, the current study aimed to further improve the acquisition of translation-ambiguous words. To attempt to mitigate the translation-ambiguity disadvantage experienced by translation-ambiguous pairs taught separately as described above, this study employed an instructional manipulation. A subset of translation-ambiguous word pairs taught second were overtrained (i.e., participants would be exposed to these words twice as many times) in an effort to produce equal learning outcomes with those translation-ambiguous pairs taught first. We hypothesized that the translation-ambiguity disadvantage of the second translation pair in recognition would be diminished, if not completely eliminated, by the experimental manipulation.

As mentioned in relation to the Terrazas study, not all individuals were able to benefit from the instructional manipulation. The examination of individual differences is an area of great interest in relation to L2 learning; my area of particular interest is musical ability. There is both anecdotal and experimental evidence relating musical ability to language learning. Thus, another aim of the current study is to further examine the relationship between musical ability/experience and L2 acquisition.

Many similarities can be drawn between music and language; they are both systems of abstract symbols that are hierarchically organized and further structured by unique syntactic principles (Patel, 2003). Although there are elements of language that do not have analogous musical counterparts, the systems function in parallel manners, just with a different set of symbols and rules. The relationship between the musical and linguistic systems is thought to stem not from their sharing of synaptic representation in the brain, but rather from their shared syntactic processing areas, or more simply, cognitive resources. This is referred to as the shared syntactic integration hypothesis (SSIH) (Patel, 2003). The exact location of these processing regions is not known; however, the theory is that there are linguistic and musical representation areas in the temporal lobe that share syntactic processing and integration centers in the frontal lobe.

A common idea relating music and language is that if one has the ability to recognize discrete musical elements, they must also have an equally attuned ear for elements of speech, regardless of the language. Thus, individuals with a more attuned ear would both be more proficient language learners and maintain a more accurate pronunciation in L2, because of their ability to recognize erroneous intonation, pitch, cadence, etc. (Slevc & Miyake, 2006). This concept of an attuned ear can be understood in the musical sense when examining melodic phrases with expected and unexpected harmonic element.

A study examining late L2 learners' proficiency (as determined by their receptive phonology, productive phonology, syntax, and lexical knowledge) and their related musical abilities found that only receptive and productive phonology were predicted by objective musical ability (Slevc & Miyake, 2006). Objective musical ability was examined in this study using the Wing Measures of Musical Talents (Wing, 1968). However, measures of subjective musical ability, measured via participants' self-ratings, were only weakly correlated with L2 performance.

Narzikul, Tolentino, and Tokowicz (2015) conducted an event-related potential study examining L2 learning and musical ability. They taught native English speakers with no prior exposure to Swedish a miniature version of Swedish vocabulary and syntax and examined performance on a posttest grammaticality judgment task. On the one hand, objective musical ability, measured by the Musical Ear Test (MET; Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010), was associated with online processing as measured using event-related potentials. On the other hand, subjective musical experience, measured with the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen, Gingras, Musil, & Stewart, 2014) was positively correlated with posttest grammaticality judgement accuracy (Narzikul et al., 2015). This study therefore demonstrates links between both subjective and objective musical ability and L2 learning.

Another study investigated the relationship between phonological production, working memory, pitch perception, and musical training (Posedel, Emery, Souza, & Fountain, 2011).

Native English speakers learning Spanish were judged on their Spanish diction. Musical training was linked to better working memory and pitch perception, while only pitch perception was directly related to correct Spanish pronunciation. The increased ability to perceive pitch as a result of increased musical training mediated the relationship between training and production. These findings complement those of Slevc and Miyake (2006), in that productive and receptive phonology were predicted by musical ability, as they were here, whereas syntax and lexical knowledge were related to other individual differences (i.e. experience with language, language use, and phonological short-term memory). To add to these findings, Cooper and Wang noted the transferability of musicality into the domain of word learning (2002).

The failure to find a clear link between musical ability and lexical knowledge may lead one to believe that there should be no relationship between musical ability and vocabulary learning, however, recent work has begun to examine the relationship between musical ability/experience and executive functions. Executive control functions are often thought of in three broad categories: inhibition, updating/working memory, and switching/flexibility (Diamond, 2013). Each of these categories has been examined with respect to music both by correlational and experimental studies. There are many reasons to believe that musical ability should have strong connections to each of these cognitive functions (e.g., sight reading requires tremendous updating/working memory; playing music within an orchestra setting depends on inhibitory control and switching capabilities) (Slevc, Davey, Buschkuehl, & Jaeggi, 2016), however there are mixed results. Some studies have found that musical ability is highly related to aspects of working memory, but not inhibitory control or switching (Slevc, et. al., 2016; Okada & Slevc, 2018). Others describe musicians as having greater cognitive flexibility, inhibitory control, and working memory as compared to non-musicians (for review, see Okada & Slevc, in press).

Slevc and Okada (2015) suggest that the executive function of cognitive control is a promising shared resource in both domains. This suggestion is based on work examining the processes of engaging with an unexpected musical or linguistic element and then being required to reinterpret previously held suppositions. Specifically, in studies in which participants read both syntactic (Slevc, 2009) and semantic (Perruchet & Poulin-Charronnat, 2013) garden path sentences, and listened to harmonically unexpected intervals, their garden path effects were more pronounced than when listening to harmonically expected intervals. There is a caveat here, however, which requires that individuals be actively engaging with both music and language.

Given the recent findings in the literature, we took this question into a new domain by studying musical ability as it relates to translation-ambiguous word learning, which is a more challenging task than standard vocabulary learning. We hypothesized that musical ability/experience would be related to the learning of translation-ambiguous words such that greater ability/experience would lead to better learning outcomes in both conditions of the experiment, standard and overtrained. Within the standard condition, we did not believe that musical ability/experience alone would be able to eliminate the translation-ambiguity disadvantage, but higher musical ability/experience would minimize the translation-ambiguity disadvantage; these findings relate primarily to the recognition task, in which we expected to see this disadvantage. We anticipated that the objective measure would be a better predictor, i.e. resulting in a stronger relationship, of translation-ambiguous word learning because rather than measuring interest or perceived exposure, it is a true measure of one's ability.

2.0 METHOD

2.1 PARTICIPANTS

Thirty-seven monolingual native English speakers (20 females) with no prior experience with Dutch or German were recruited from the University of Pittsburgh and surrounding areas. Data from six participants were excluded because they did not provide a complete dataset or were not a native speaker of American English. Participants were over the age of 18, right handed, and had normal or normal-corrected vision. At the completion of the study, participants were compensated $10 per hour. Primary recruitment occurred on the University of Pittsburgh's campus through flyers as well as departmental advertising and Facebook postings. Participants completed a language history questionnaire (Tokowicz, Michael, & Kroll, 2004, see Table 1 for participant characteristics).

Table 1 Participant Demographic Information

Gender	M	F
N	14	17
Age (years)	20.38	20.94
	Self-Rated Proficiency	
L1 Reading	9.71	9.94
L1 Writing	9.64	9.94
L1 Conversational Fluency	9.57	9.94
L1 Speech Comprehension	9.79	10
L2 Reading	4.43	3.67
L2 Writing	4.29	3.6
L2 Conversational Fluency	3.86	3.53
L2 Speech Comprehension	5.14	3.8

L1 Reading	9.71	9.94

Note: All participants identified L1 as English; Participant include of 31 individuals of the original 37 due to removal of incomplete data and data within exclusion criteria.

2.2 MATERIALS

2.2.1 German-English translation stimuli

The stimuli for this experiment consisted of 64 words: 32 translation-ambiguous and 32 translation-unambiguous German-English words. Translation ambiguous and unambiguous stimuli were matched on German word length (number of letters), English word length (first translation), and English word frequency (first translation; $SUBTLEX_{US}$ LG 10 from Brysbaert & New, 2009) (see Appendix A for stimuli).

The translation-ambiguous stimuli were separated into two groups for counterbalancing purposes; these were matched on the above variables as well as translation semantic variability (TSV; Bracken et al., 2017), German word length, English word length (both translations), and English word frequency (both translations). The lists were further counterbalanced based on these same variables, but within four subcategories representing different versions of the testing program.

2.2.2 Musical Ear Test

The Musical Ear Test (MET; Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010) is an objective musical ability task. It consists of two subtests, a melodic (MET Mel) and a rhythmic (MET Rhy) test. Participants listened to two phrases and indicated if they were the same or different. The MET is able to differentiate musical sophistication between musicians and non-musicians as well as between professional, amateur, and non-musicians. Participants heard a total of 104 trials: 52 melodic phrases (played on piano) and 52 rhythmic phrases (played on a wooden block); 26 trials in each condition were identical. The results of this task were coded based on accuracy, with correct responses being coded as one and incorrect responses as zero. The percent accuracy for the melodic and the rhythmic sections were calculated separately by summing all of the coded responses and dividing by the number of trials in that condition.

2.2.3 Mowrer Test of Tonal Memory

The Mowrer test of tonal memory is a tool used to assess an individual's objective musical ability (Mowrer, 1996). It was originally designed to examine a singer's ability and worth in a choral ensemble but has recently been referenced as an invaluable tool for determining overall objective musical ability. The task is comprised of seven melodic phrases with intervals no greater than a fourth, clear tonal centers, and variable difficulties. After each melodic phrase was played, participants were prompted to sing the phrase back using the syllable "da." In the present study, the task was administered via PowerPoint and responses were recorded using an external recording device. Responses were coded based on a five-point scale: 5: The tonal pattern is accurately reproduced with good intonation; 4: The tonal pattern is correctly reproduced, but with some uncertainty; 3: Melodic direction is evident, but some tones are incorrectly reproduced; 2: Melodic direction is evident, but no tones are correctly produced; 1: Reproduction of the tonal pattern is not recognizable. Each participants' summed accuracy across all seven items was calculated, with the range of possible scores being 5-35 (Norris, 2000).

2.2.4 Goldsmiths Musical Sophistication Index

The Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen, Gingras, Musil, & Stewart, 2014) is a measure of subjective musical ability and musical sophistication. The Gold-MSI is a self-report questionnaire consisting of six subscales: active engagement, perceptual abilities, musical training, singing abilities, emotions, and general musical sophistication. This task was administered via an online Qualtrics survey and was subsequently scored according to the Gold-MSI guidelines. The first 32 questions were answered based on an agreement scale (7=Completely Agree, 6=Strongly Agree, 5=Agree, 4=Neither Agree Nor Disagree, 3=Disagree, 2=Strongly Disagree, 1=Completely Disagree). The subsequent seven questions provided numerical answers; all were converted to units of hours. The numerical sum of the responses from questions 1-39 was tabulated for each participant to create the overall Gold-MSI score. The final two questions of this survey provided qualitative responses which were not included in the numerical sum (see Appendix B for complete survey).

2.2.5 Language History Questionnaire

The language history questionnaire is an assessment of participants' general experiences with language (Tokowicz et al., 2004). It verifies that participants meet inclusion criteria for the study and also examines elements of their first and additional languages. Participants are first asked to provide a general overview of their language knowledge (e.g. L1, L2, additional languages, years of language study, languages spoken at home, etc.) Then, on a ten-point Likert-type scale, participants rate their L1 and L2 reading proficiency, writing proficiency, conversational fluency, and speech comprehension ability. Additional questions ask about their learning style and familial and personal educational attainment. This survey was administered via Qualtrics (see Table 1 for LHQ summary; see Appendix C for complete questionnaire).

2.3 PROCEDURE

This study was conducted in three sessions over three days (e.g., MWF) (see Table 2 for an overview of the tasks performed on each session).

Table 2 Tasks by Session

Session Number	1	2	3
Tasks	1. Consent 2.German-English translation 1 training 3. 30 second math distractor task 4. Free Recall	1.Translation recognition task 1 2.German-English translation 2 training 3. 30 second math distractor task 4. Free recall	1.Translation recognition task 2 2.Musical Ear Test (MET) 3. Mowrer Test of Tonal Memory 4.Goldsmiths musical sophistication Index (Gold-MSI) 5. Language history questionnaire 6. Compensation & Debriefing

Session 1 began by training participants on a series of German-English translation pairs using E-Prime software. The training paradigm worked as follows: a fixation cross appeared on the center of the screen; participants pressed the center button on the button box to advance the screen; the fixation cross was then replaced by a German-English translation pair, which stayed on the screen for 8000 ms until it was again replaced by a fixation cross. Participants completed four practice trials to familiarize themselves with the learning paradigm. They then began the actual learning phase. The participants were not able to self-pace through the translation pair presentation but were able to advance to the next pair once they saw the fixation cross by pressing the “3”. On Session 1 they were trained on 16 unambiguous words and 32 translation-ambiguous words. Each word was trained three times. For the translation-ambiguous words, participants received only one of the two translations during Session 1. Following training, participants completed a 30-second math distractor task in which they were asked to verify multiplication problems (e.g., 2 x 2 = 4, 2 x 3 = 8) by pressing 1 (incorrect) or 5 (correct) on a button box. This short math distractor task was included to improve learning through a delay between studying and testing, a method described in previous literature (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). The math distractor is placed in between training and testing (e.g., free recall), which is used as a means of learning reinforcement described by the testing effect (Bahrick, 1979).

Session 1 concluded with participants completing a free recall task for the previously-trained words. This free recall task was intended to be a tool for reinforcement of learning but was also used for exploratory analyses. Participants were given an Excel spreadsheet with two columns, one with the heading “German” and the other “English.” They were asked to try to recall as many of the German-English translation pairs that they learned earlier in the session as possible. Furthermore, if they could not remember the pairs, they were asked to write down any individual German or English words that they could remember as a means to solidify their knowledge. Participants left and were reminded to return for Session 2.

Session 2 began with a translation recognition task for the translation pairs learned during Session 1. Participants sat at the computer and were asked to verify using a button box whether presented German-English translation pairs were accurate or not (leftmost button = incorrect, rightmost button = correct). The word pairs were presented using E-Prime software; they were presented in a random order with an equal frequency of "yes" trials (i.e., translations) and "no" trials (i.e., unrelated) pairs. The unrelated pairs were created by pairing German words with randomly selected English translations already present within the stimulus set. For example, instead of seeing Erzeugung = creation (a correct translation), they would see Erzeugung = tension (an unrelated pair). Participants' reaction time and accuracy in recognizing the translations and unrelated pairs, were collected. We initially intended for the translation recognition task to be the main measure for learning outcome analyses.

Following this task, participants were again trained on German-English translation pairs. They were trained on 16 novel unambiguous word pairs as well as the same 32 translation-ambiguous words as before. However, they were taught the previously-unlearned translation for the ambiguous words (translation two). The 32 ambiguous-translation pairs learned during Session 2 were evenly distributed between two training conditions: overtrained and standard. In the overtrained condition, 16 unambiguous words were presented twice as frequently as words in the standard condition. The 16-remaining translation-ambiguous words were in the standard condition. These words were trained at frequency equal to that of the unambiguous words. In this standard training condition, each word was presented once per cycle for three cycles—a total of three exposures. In the overtrained condition, there were again three cycles of training, but each word was presented two times per cycle, for a total of six exposures. There is the potential that having the translation recognition task at the beginning of Session 2 could have biased this second training. Specifically, they could have experienced interference effects from the translations learned during Session 1. As in Session 1, participants then completed the math distractor task and free recall task. The free recall task was identical to that of Session 1, except that there was a single column entitled “German” and two columns entitled “English.” Participants were told that some of the words may have more than one English translation. They were asked to write down both translations if applicable, but if they could not remember both, to write down any part of the translation pairs that they could remember. Participants were then reminded to return for Session 3.

Session 3 began with a translation recognition task for all of the word pairs learned in Sessions 1 and 2. At this point, participants completed the musical ability and musical experience tasks, as detailed above. First, they were tested on the MET melody and MET rhythm tasks. They then completed the Mowrer Test of Tonal Memory. Participants then completed two surveys, the Gold-MSI and a language history questionnaire, both administered via Qualtrics. Finally, participants were compensated and debriefed.

3.0 RESULTS

The results presented address three hypotheses. All word-learning outcomes were measured as accuracies on free recall and translation recognition tasks. First, we looked at the learning outcomes for translation-unambiguous words and translation-ambiguous words. Hypothesis 1 stated that translation-ambiguous words would be recalled better, whereas translation-unambiguous words would be recognized more accurately. Our second hypothesis explored the effect of manipulating the frequency of training of the second translation of translation-ambiguous words. Hypothesis 2a stated that the second translation of translation ambiguous words in the overtrained condition would experience equal learning outcomes to the first translation. Hypothesis 2b indicated that the second translation in the overtrained condition would experience equal learning outcomes to translation-unambiguous words. The third question we explored related to the relationship between subjective and objective musical ability on translation-ambiguous word learning. This question was analyzed in four ways, i.e. by each index of musical ability/experience. The overarching hypothesis was that there would be an interaction between musical ability and translation-ambiguous word learning.

3.1 ANALYSIS APPROACH

The data were analyzed using linear mixed effects models. What is unique about these models are their ability to include information about both subject and item variables simultaneously. These models include fixed effects, which are the independent variables of interest (number of translations, training condition—overtrained and standard, musical ability, musical sophistication, TSV) and random effects arising from the sample and stimuli (participants and items). The models were examined using the lmer and glmer commands of the lmerTest package (RStudio Team, 2016).; glmer is a command for binomial regression and was used for translation accuracy (Kuznetsova, Brockhoff, & Christensen, 2013) and lmer was used for reaction time analyses. Figures were produced using sjplot and ggplot2 in RStudio. Language learning was assessed behaviorally using accuracy and response time on the translation-recognition task as well as the accuracy on the free recall task. Free recall accuracy was used as the primary measure of learning.

3.2 DATA PROCESSESING

This study examined the relationships between learning translation-ambiguous words and training frequency as well as musical ability. Data processing was conducted separately for free recall and translation recognition.

The primary data of interest for free recall were obtained during Session 2 of the study after all translations had been trained. Free recall was coded on whether or not the translation pair/triplet was recalled in its entirety ("EntireACC"). Specifically, an unambiguous word had to have both its German and English translations correctly recalled, or a translation-ambiguous word had to have the German word and both English translations correctly recalled—the order of translation recall was not noted. This variable was coded as 0 for incorrect and 1 for entirely correct. For the analysis of translation-ambiguous words only, we examined whether *both* English words were correctly recalled (i.e., scored as 0 for one or both wrong, 1 for both correct) when the German word was correctly recalled.

Our reaction times (RTs) were skewed to the right. For this reason, we examined the distribution of the correct trial RTs and looked for the point at which we would maintain 97% of the data, while removing responses that seemed to be outliers. Accordingly, we removed 1 RT faster than 100 ms and 66 RTs slower than 6,000 ms; this resulted in the removal of a total of 67 trials.

To examine the independent effects of musical ability on translation-ambiguous word-learning, we created multiple models, each unique in their interaction terms. We began by examining the free recall data in relationship to the musical ability measures (MET-Melody, MET-Rhythm, Mowrer, Gold-MSI[1]; see Table 3 for descriptive statistics of the musical tasks). Within each pair of models, we present, we first analyzed the effect of translation ambiguity and then looked only at the ambiguous words to examine the effects of training condition (standard or overtrained) as well as the effect of TSV. Each model included German word length, English word length, English word frequency, and English word concreteness as fixed effects as well as the interaction term Ambiguity: Musical Measure. For models examining translation ambiguous words only, we additionally included TSV and training condition as interaction terms. Note that we did not use * (the asterisk is R specific syntax that indicates that the main effects are being forced into the model) and therefore lower-level main effects were not forced into our model;

these main effects were not of primary interest and by not including them, we had more streamlined models and were able to include a maximal effects structure for most models (e.g., Barr Levy, Scheepers, & Tily, 2013). Models within each group (i.e. translation ambiguity, training condition) were compared using Akaike's Information Criterion (AIC) to determine which musical task predicted the best model. AIC estimates the quality of a model based on the amount of information lost. The lower Akaike's number, the less information lost, the better the model fit. Models revealing three-way interactions and presenting the lowest AIC score were further examined. Only the fixed effects tables for the best-fitting models are presented below; fixed effects tables for all other models can be found in Appendix D.

Table 3. Descriptive Statistics of Musical Ability and Experience Tasks

Musical Ability/Experience Task	Mean	Range	Standard Deviation
Musical Ear Test: Melody	0.68	0.48-0.88	0.12
Musical Ear Test: Rhythm	0.69	0.52-0.87	0.10
Mowrer Test of Tonal Memory	2.97	1.14-4.71	1.08
Goldsmiths Musical Sophistication Index	144.32	84.13-198.00	20.18

3.2.1 Free Recall

Of the four models we ran to investigate the relationship between translation ambiguity and musical ability on free recall, the model that included MET Melody had the lowest AIC (1684.6; see Table 4; see Tables 12 and 13 in Appendix D for other models). There was a main effect of German word length such that longer German words had poorer free recall accuracy (β = -0.18, z = -2.95, p < 0.01). Furthermore, there was an interaction between translation ambiguity and MET Melody (see Figure 1); the interaction indicated that translation-ambiguous words were recalled more accurately overall, and that both word types were recalled more accurately in participants with higher MET Melody scores ($\beta_{ambig} = 4.43$, $z = 3.09$, $p < 0.01$; $\beta_{unambig} = 3.64$, $z = 2.56$, $p < 0.05$), but that the effect of MET Melody was larger among ambiguous words.

Table 4 Fixed Effects for the Model for Free Recall with Ambiguity and Musical Ear Test: Melody as a Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-2.43	1.49	-1.63	0.10	
German Length	-0.18	0.06	-2.95	0.00	*
English Avg. Length	-0.09	0.09	-1.08	0.28	
English Avg. Frequency	-0.23	0.25	-0.93	0.35	
English Avg. Concreteness	0.01	0.01	1.64	0.10	
TransAmbiguityAmbig: Musical Ear Test: Melody	4.43	1.44	3.09	0.00	*
TransAmbiguityUnambig: Musical Ear Test: Melody	3.64	1.42	2.56	0.01	*

*Note:*glmer(EntireAcc~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+ TransAmbiguity:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TransAmbiguity:METMel || Participant),data=EleannaRecallData, family=binomial,glmerControl (optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

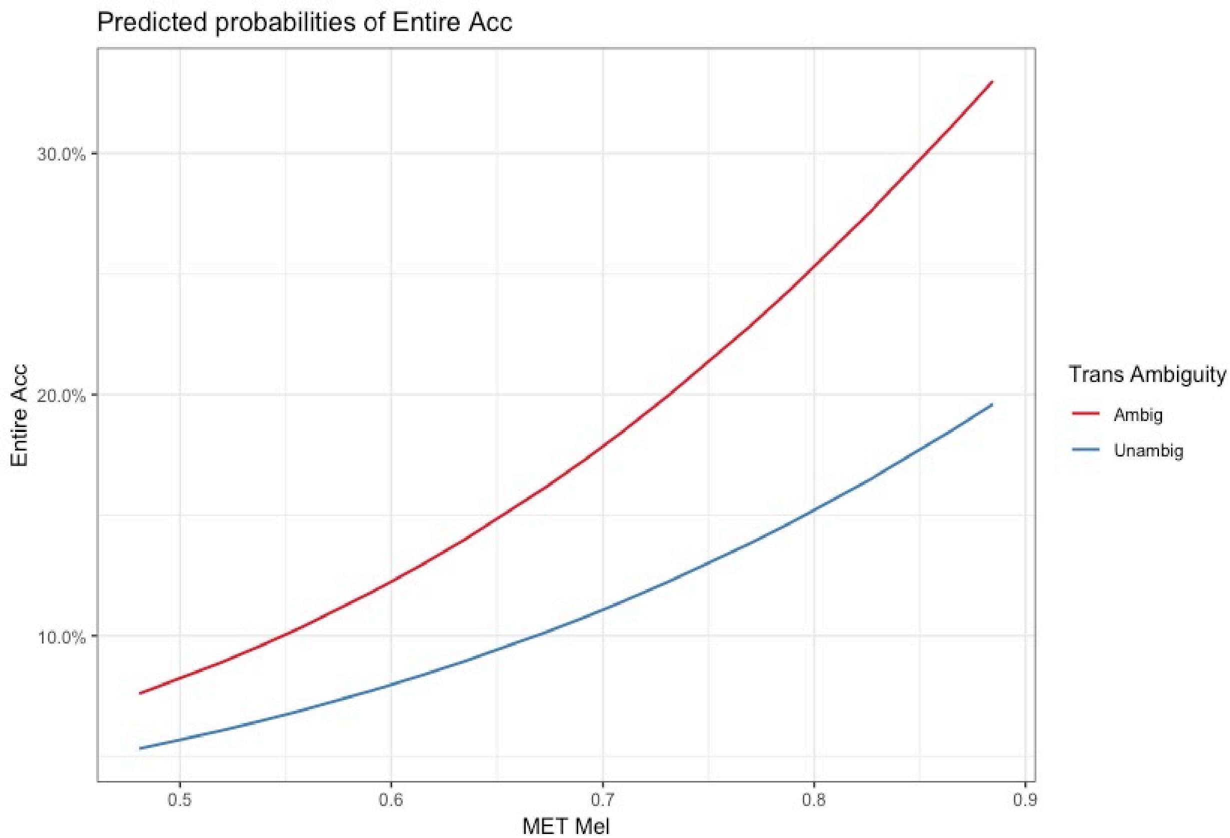

Figure 1 Entire Accuracy on Free Recall as an Interaction between MET Melody and Translation Ambiguity

Of the four models we ran to investigate the relationship between training condition and musical ability on free recall, the model that included MET Rhythm had the lowest AIC (894.2; see Table 5; see Tables 14-17 in Appendix D for other models). MET Rhythm interacted with training condition, such that as MET Rhythm increased so did free recall accuracy in the overtrained and standard conditions ($\beta = 5.70_{\text{overtrained}}$, $z = 2.61$, $p < 0.01$; $\beta_{\text{standard}} = 5.54$, $z = 2.53$, $p < 0.05$; see Figure 2. The effect of MET Rhythm was slightly larger in the overtrained condition.

Table 5 Fixed Effects for the Model for Free Recall with Training Condition and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-2.91	2.19	-1.33	0.18	
German Length	-0.14	0.10	-1.44	0.15	
English Avg. Length	-0.28	0.15	-1.89	0.06	.
English Avg. Frequency	-0.21	0.34	-0.60	0.55	
English Avg. Concreteness	0.01	0.01	0.98	0.33	
TSV	0.07	0.12	0.57	0.57	
TrainingConditionOvertrained: Musical Ear Test Rhythm	5.70	2.19	2.61	0.01	**
TrainingConditionStandard: Musical Ear Test Rhythm	5.54	2.19	2.53	0.01	*

Note: glmer(BothTrans~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc +TSV+TrainingCondition:METRhy+(1|Participant)+(1|GermanWord)+(0 + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TSV+TrainingCondition:METRhy || Participant),data=EleannaRecallData.Ambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1000000)))

. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

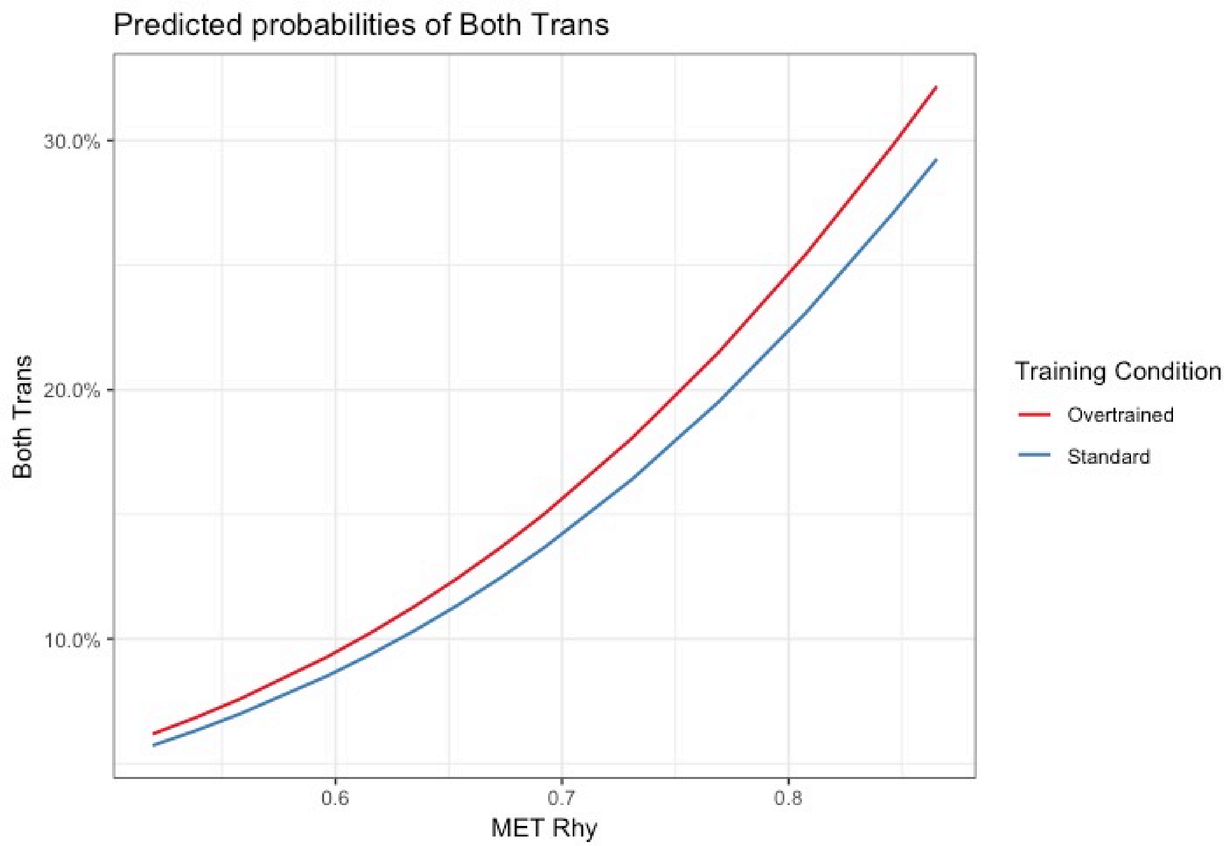

Figure 2 Predicted Accuracy of Free Recall Measured as a Function of MET Rhythm and Training Condition

3.2.2 Translation Recognition Accuracy

Of the four models we ran to investigate the relationship between translation ambiguity and musical ability on translation recognition accuracy, the model that included MET Melody had the lowest AIC (1734.7; see Table 6; see Tables 18 and 19 in Appendix D for other models). This model revealed a main effect of English concreteness ($\beta = 0.19$, $z = 2.75$, $p < 0.01$), such that more concrete words had higher translation recognition accuracy. There was also an interaction between ambiguity, pair relatedness, and MET Melody ($\beta_{\text{ambiguous translation}} = 4.17$, $z =$

2.49, $p < 0.05$; $\beta_{\text{unambiguous translation}} = 4.42$, $z = 2.68$ $p < 0.05$; $\beta_{\text{ambiguous unrelated}} = 4.35$, $z = 2.62$, $p < 0.01$; $\beta_{\text{unambiguous translation}} = 4.79$, $z = 2.89$, $p < 0.01$ see Figure 3).

Table 6 Fixed Effects for the Translation Recognition Accuracy Model with Ambiguity, Relatedness, and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-0.80	1.34	-0.60	0.55	
German Length	-0.07	0.04	-1.81	0.07	.
English Length	-0.06	0.05	-1.16	0.25	
English Frequency	-0.02	0.14	-0.16	0.87	
English Concreteness	0.19	0.07	2.75	0.01	**
TransAmbigAmbig:relatednesstranslation: Musical Ear Test: Melody	4.17	1.67	2.49	0.01	*
TransAmbigUnambig:relatednesstranslation: Musical Ear Test: Melody	4.42	1.65	2.68	0.01	**
TransAmbigAmbig:relatednessunrelated: Musical Ear Test: Melody	4.36	1.66	2.62	0.01	**
TransAmbigUnambig:relatednessunrelated: Musical Ear Test: Melody	4.79	1.66	2.88	0.00	**

*Note:*glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig: relatedness:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METMel || Participant),data=EleannaTRData.StdandUnambig, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

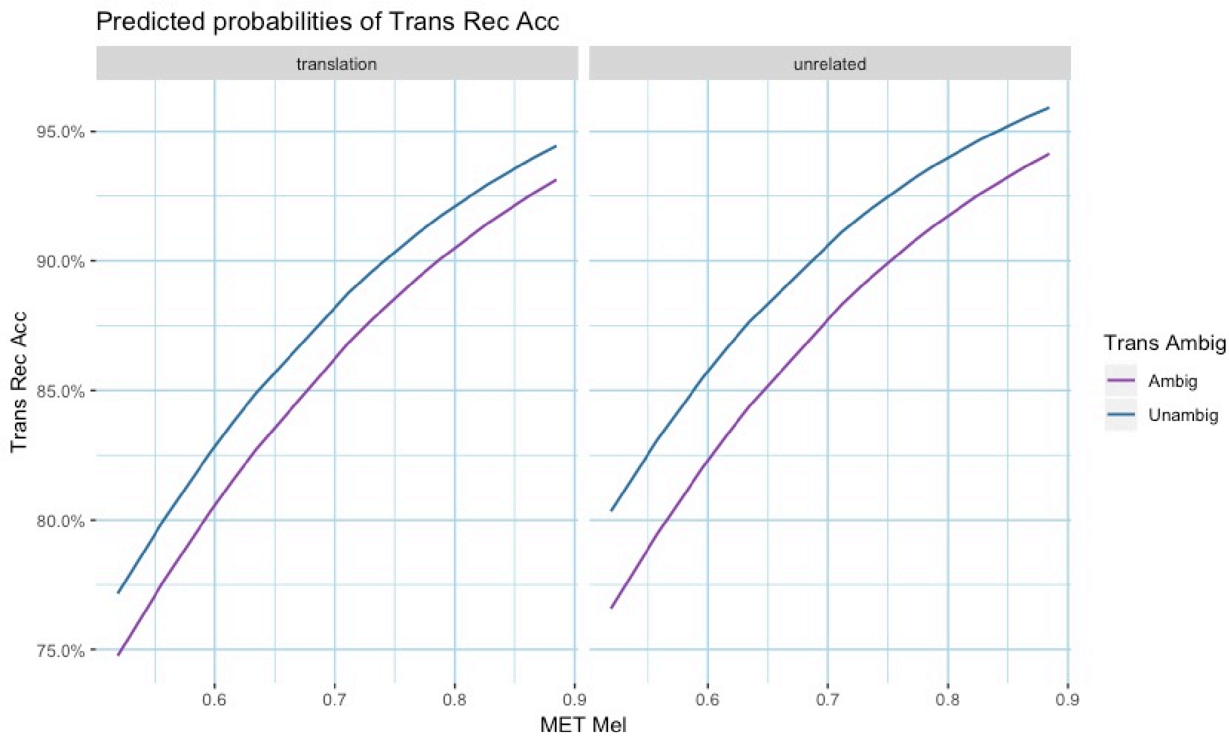

Figure 3 Predicted Accuracy of Translation Recognition measured as a Function of MET Melody and Ambiguity

A follow up analysis was conducted in which the data were separated into two subsets: ambiguous and unambiguous. The follow-up analysis examining ambiguous words exhibited an interaction between translation pairs and MET Melody (β = 3.69, z = 2.43, p < 0.05) and unrelated pairs and MET Melody (β = 3.67, z = 2.43, p < 0.05). These analyses indicate that as MET Melody scores increase, correct recognition of both translation pairs and unrelated pairs increase (see Table 7). The follow-up analysis looking at unambiguous words demonstrated a main effect of English concreteness (β = 0.24, z = 2.28, p < 0.05) as well as an interaction between translation accuracy and MET Melody (see Table 8). Specifically, translations interacted with MET Melody (β = 4.25, z = 2.57, p < 0.05) as did unrelated pairs (β = 4.70, z = 2.81, p < 0.01). This interaction indicates that the greater the MET Melody score, the great the translation recognition accuracy for unambiguous words. This effect was more pronounced for unrelated pairs.

Table 7 Fixed Effects for the Translation Recognition Accuracy Model Follow up for Ambiguous

Fixed effect	*β*	SE	z value	Pr(>|z|)	
Intercept	-0.87	1.27	-0.68	0.49	
German Length	-0.06	0.06	-0.98	0.33	
English Length	0.07	0.05	1.38	0.17	
English Frequency	-0.14	0.12	-1.12	0.26	
English Concreteness	0.13	0.08	1.65	0.10	.
Relatednesstranslation: Musical Ear Test: Melody	3.69	1.52	2.43	0.02	*
Relatednessunrelated: Musical Ear Test: Melody	3.67	1.51	2.43	0.02	*

Note:glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+relatedness: METMel+(1|Participant)+(1|GermanWord)+(0+ GermanLength+EngLen+EngFreq+EngConc+relatedness:METMel|| Participant),data=EleannaTRData.Ambiguous,family=binomial,glmerControl(optimizer= "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.05* ** p < *.01* *** p < *.001*

Table 8 Fixed Effects for the Translation Recognition Accuracy Model Follow up for Unambiguous

Fixed effect	*β*	SE	z value	Pr(>|z|)	
Intercept	-2.04	1.74	-1.18	0.24	
German Length	-0.07	0.05	-1.31	0.19	
English Length	-0.03	0.08	-0.44	0.66	
English Frequency	0.31	0.27	1.18	0.24	
English Concreteness	0.24	0.11	2.28	0.02	*
Relatednesstranslation: Musical Ear Test: Melody	4.25	1.66	2.57	0.01	*
Relatednessunrelated: Musical Ear Test: Melody	4.70	1.67	2.81	0.00	**

Note:glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+relatedness: METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+relatedness:METMel || Participant),data=EleannaTRData.Unambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.05* ** p < *.01* *** p < *.001*

Further analyses were done to examine translation recognition accuracy among ambiguous words and training condition. These models only included translation pairs. Of the four further analyses that were run, the model incorporating Mowrer had the lowest AIC score (1767.9; see Table 9; see Tables 20-23 and 31-33 in Appendix D for other models). This model illustrated only a main effect of TSV (β = 0.05, z = 2.21, p < 0.05) and no effects of training condition.

Table 9 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition and Mowrer as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	1.87	1.23	1.52	0.13	
German Length	0.00	0.07	-0.03	0.98	
English Length	-0.08	0.08	-1.03	0.30	
English Frequency	-0.17	0.19	-0.92	0.36	
English Concreteness	0.19	0.11	1.69	0.09	.
TSV	0.05	0.02	2.21	0.03	*
TrainingConditionStandard	0.48	0.58	0.83	0.41	
TrainingConditionOvertrained: Mowrer	-0.11	0.26	-0.43	0.67	
TrainingConditionStandard: Mowrer	-0.33	0.24	-1.37	0.17	

*Note:*glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+TrainingCondition:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:Mowrer || Participant),data=EleannaTRData.relatedTAonly, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

3.2.3 Translation Recognition Reaction Time

None of the models examining translation recognition reaction time yielded significant effects for the variables of interest; only word level effects reached conventional levels of significance. Of the four models run examining reaction time and ambiguity, the model including LG10GOLD (a rescaled version of the Goldsmiths Musical Sophistication Index score) had the lowest AIC score (38698; see Table 10; see Tables 24-26 in Appendix D for other models). This model demonstrates main effects of German word length (β = 54.4879, t=3.05, p < 0.01), indicating that the longer the German word, the slower the reaction time, and English concreteness (β = -53.64, z = 2.367 p < 0.05), indicating that the more concrete the English word, the faster the reaction time.

Table 10 Fixed Effects for the Translation Recognition Reaction Time Model with Ambiguity, Relatedness, and Goldsmiths Musical Sophistication Index as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
Intercept	7037.01	3671.25	32.67	1.92	0.06	.
German Length	54.76	17.97	56.35	3.05	0.00	**
English Length	7.92	14.17	1379.75	0.56	0.58	
English Frequency	-10.52	44.58	244.68	-0.24	0.81	
English Concreteness	-53.64	22.62	773.77	-2.37	0.02	*
TransAmbigAmbig: relatedness translation: LG10GOLD	-2485.33	1699.29	32.36	-1.46	0.15	
TransAmbigUnambig: relatedness translation: LG10GOLD	-2502.83	1699.64	32.43	-1.47	0.15	
TransAmbigAmbig:r elatedness unrelated: LG10GOLD	-2393.52	1699.67	32.36	-1.41	0.17	
TransAmbigUnambig: relatedness unrelated: LG10GOLD	-2444.43	1699.23	32.41	-1.44	0.16	

*Note:*lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+ TransAmbig:relatedness:LG10GOLD+(1|Participant)+(1|GermanWord)+(0+ GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:LG10GOLD|| Participant),data=EleannaTRData,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Just as with the accuracy results presented above, we examined reaction time among translation ambiguous words only to see the effects of training condition and musical ability. From the four models we ran, the model incorporating MET Rhythm had the lowest AIC score (11539; see Table 11; see Tables 27-30 and 34-36 in appendix D for other models). There was a significant effect of English concreteness (β = -103.65, t = -2.02, p < .05) indicating that the more concrete the English word, the faster the recognition.

Table 11 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
Intercept	891.82	822.33	52.00	1.09	0.28	
German Length	59.59	36.96	35.46	1.61	0.12	
English Length	24.35	31.58	157.04	0.77	0.44	
English Frequency	-43.48	85.36	107.15	-0.51	0.61	
English Concreteness	-103.65	51.36	51.43	-2.02	0.05	*
TSV	-7.59	6.05	28.99	-1.25	0.22	
TrainingConditionStandard	-95.04	605.37	21.76	-0.16	0.88	
TrainingConditionOvertrained: Musical Ear Test: Rhythm	1422.98	1000.23	29.96	1.42	0.17	
TrainingConditionStandard: Musical Ear Test: Rhythm	1666.30	964.95	23.98	1.73	0.10	.

*Note:*lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+ TrainingCondition:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:METRhy || Participant),data=EleannaTRData.relatedTAonly, control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

4.0 DISCUSSION

This study sought to examine how training condition and musical ability/experience interact with the learning of translation-ambiguous words. To delve into this question, the study had three main aims: examine learning outcomes between unambiguous and ambiguous words, analyze translation-ambiguous words in the overtrained and standard conditions, and investigate the relationship between musical ability/experience and word learning performance.

The first aim was to revisit a previously-studied question, namely, whether translation-unambiguous words are learned better than translation-ambiguous words[2]. Hypothesis 1 posited that if unambiguous words and ambiguous were learned the same number of times, unambiguous words would have better learning outcomes. Specifically, unambiguous words would be recognized more accurately, whereas ambiguous words would be recalled more accurately. Hypothesis 1 was partially supported. We found that participants recalled ambiguous words more accurately than unambiguous words. None of our recognition accuracy results were significant, however, so we cannot make claims about the relationship between ambiguity and learning in terms of recognition. We believe this could be due to the already high mean recognition scores among the participants. This pattern of ambiguous words being recalled better than unambiguous words is in line with the work of Degani, Tseng, and Tokowicz (2014), who found that items that stand out as being more challenging to learn tend to be recalled better but recognized worse.

The second hypothesis sought to understand how varying training frequency affects word-learning outcomes. Hypothesis 2a stated that ambiguous words in the overtrained condition would be recalled and recognized more accurately than ambiguous words in the standard condition. This hypothesis was supported. We found that during free recall, words in the overtrained condition were recalled more accurately than words in the standard condition. These findings are striking because the frequency manipulation was quite subtle. In future studies the effect may become even more pronounced with a greater number of presentations (e.g., 3x or 4x the standard condition). In terms of standard and overtraining conditions, we had no significant findings on the measure of translation recognition. Hypothesis 2b analyzed the differential learning outcomes between the first and second translation of translation-ambiguous words. We believed that the second translation in the standard condition would have poorer learning outcomes, whereas the second translation in the overtrained condition would have learning outcomes equal to the first translation. Hypothesis 2c concerned the learning outcomes between ambiguous words in the overtrained condition and unambiguous words. We hypothesized that ambiguous words in the overtrained condition would be learned as well as the unambiguous words, thereby eliminating the translation-ambiguity disadvantage.

The third area of interest of this study was between translation-ambiguous word learning and musical ability and experience. We examined each of our musical ability/experience tasks with learning outcomes, measured by free recall and translation recognition accuracy and reaction time. Outcomes were compared between translation-ambiguous and unambiguous words as well as among ambiguous words in the different training conditions. After conducting all of the analyses, the best-fitting models, as determined by AIC scores, were further explored. We hypothesized that higher musical ability scores (MET Melody, MET Rhythm, and Mowrer) would positively interact with translation-ambiguous word-learning, whereas subjective musical experience scores (Gold-MSI) would not be related to learning outcomes.

When we analyzed the free recall data examining musical ability and ambiguity, the best-fitting model used MET Melody as a predictor. This model found that the greater the MET Melody score was, the greater the accuracy of free recall for both ambiguous and unambiguous words. There appeared to be a greater effect of MET Melody scores on ambiguous word recall than for unambiguous words. Examining only ambiguous words' free recall outcomes as a function of training condition, we found that MET Rhythm was the best predictor of learning outcomes. Higher MET Rhythm scores predicted greater recall accuracy for both ambiguous and unambiguous words. The effect was larger for ambiguous words in the overtrained condition than the standard condition. When we looked at translation recognition accuracy, in terms of its most predictive model using Mowrer, we found that the higher the Mowrer score, the greater the recognition accuracy. The effect was more pronounced for unambiguous words than for ambiguous words, but this finding was not significant.

Based on past literature, there was very little reason to think that there would be such significant interactions between musical abilities and lexical learning. Music and language have been equated based on their shared nature—being comprised of abstract symbols strung together through unique syntaxes. Both language and musical structural understandings follow similar developmental trajectories (Slevc & Okada, 2015). The processing of language and music has been hypothesized to share brain circuitry resources. Receptive and productive phonology, but not lexical learning, have been predicted by objective musical ability (Slevc & Miyake, 2006). Much of the research to date has supported the shared syntactic integration hypothesis (SSIRH) for musical structures sharing resources necessary for syntactic processing (Patel, 2003). Moving beyond purely syntactic processing, it has also been noted that musical structure and language processing become intertwined when processing an unexpected element and then cognitively reinterpreting the information (Slevc & Okada, 2015). A common place where this pattern of recognition of unexpected patterns requiring reinterpretation are often seen is in garden path sentences. These are sentences in which a reader falsely assigns value to a component of a grammatically correct sentence due to the structure of the sentence. In studies simultaneously examining garden path sentences (both semantic and syntactic) and predicted or unpredicted musical harmonies, participants who heard unexpected chords illustrated greater garden path effects (Slevc, 2009; Perruchet & Poulin-Charronnat, 2013). For example, when participants read a garden path sentence and heard a chord that did not fit the harmonic arrangement established up to that point, the participant would spend more time recovering from the misinterpretation of the sentence, as compared to those who heard an expected musical chord. It is promising to see the interaction of music and language processing beyond purely syntactic settings.

What ties these areas together is the need to reorganize new information to understand the situation, be it in the sentence or in the musical phrase. The ability to do this is enabled by cognitive control. To understand further the influence of cognitive control as a shared resource for music and language, studies have examined the Stroop task (a task of cognitive control; Stroop, 1935) accompanied by harmonically expected and unexpected chords (Masataka & Perlovsky, 2013; Slevc et al. 2013). Unexpected harmonic intervals led to more severe Stroop effects. This effect illustrates shared resources between cognitive control and musical ability. Therefore, if we believe that cognitive control is implicated in language and music, we could hypothesize that it is the crucial shared resource underlying the interconnectedness of the two domains.

In the current study, we did not examine either musical or linguistic garden path sentences, but we did create a situation in which participants had to reorganize and reinterpret information. Participants learned the first translation of translation-ambiguous words during Session 1, during which time they created a 1:1 mapping. During the second session they learned the second translation of translation-ambiguous words, and therefore had to create new 1:2 mappings. This may require the use of cognitive control. If in fact musical processing and linguistic processing both use cognitive control as a basic mechanism for higher order processing, it is intuitive that participants with greater cognitive control capabilities would have both higher musical abilities as well as lexical learning abilities (Slevc & Okada, 2015).

This idea is consistent with research by Terrazas (2018) who found that to benefit from the training manipulation (i.e., presenting translation-ambiguous words with a blank line indicating there will be a 1:2 mapping), participants necessarily needed cognitive advantages. One of these cognitive advantages was the ability to ignore task-irrelevant information, which was measured the Stroop task. Unfortunately, we did not have measures of cognitive control abilities in our study.

This study has both strengths and weaknesses. One strength is that it was novel in its questions and provided insight into the growing area of musical and linguistic research. The literature provides work relating language processing with melody, timbre, and harmony, but not with rhythm (Kunert & Slevc, 2015). Rhythm was found to be the most significant predictor in one of our models and is thus an important factor to consider in future studies. Some previous research has examined lexical learning and musical ability, but none has examined translation-ambiguity specifically. Translation ambiguity is a topic of study in language learning because it affects learning outcomes, but ambiguity as a whole is not restricted to language. Musical ambiguity is also an area of study, because musical processing is altered when people experience ambiguity. Another strength of this study was that there was robust testing for German-English translation pairs as well as testing of musical ability/experience. Participants were tested on the German-English translations on all three sessions. They completed two free recall tasks (session 1 and 2) to both enhance their learning as well as test them, and they also completed two translation recognition tasks to examine their learning outcomes using different cognitive mechanisms. The musical ability/experience testing was robust in that participants' ability was assessed melodically (MET Melody), rhythmically (MET Rhythm), and physically (Mowrer). Each of these tests have been validated instruments for assessing musical ability (Mowrer, 1996; Wallentin, et. al., 2019) and the scores from the four different tasks are correlated (see Appendix E for correlations). Participants' subjective musical experience were measured using a single task (the Gold-MSI) which has also been validated in previous work (Müllensiefen et. al., 2014).

It is evident that there were interactions between musical ability and lexical learning for ambiguous and unambiguous words. In this study we employed multiple tests of musical ability, and different models yielded different predictors. It would be beneficial if there was a single test of objective musical ability which would consistently provide the best fitting model. A possible mechanism to achieve this would be to extend the Mowrer task further or develop a less subjective coding method for the Mowrer test, such as a digitized comparison method (Miyake & Slevc, 2006). Alternatively, the various tests we used could be combined, possibly using a factor analysis (e.g., Okada & Slevc, 2018). The more pressing area of future research, however, is to examine the underlying neural mechanisms that can account for the interaction between musical ability and word learning. The SSIRH (Patel, 2003) hypothesis is a good point to begin to think about the nature of musical and linguistic connectivity. A promising specific shared cognitive resource for musical and linguistic processing is cognitive control. Although there is literature showing that there is co-localization (as presented with neuroimaging and neurophysiological responses) between linguistic processing and musical processing, there have been mixed results. Ideally, future research will examine musical and linguistic interactions such as to engage aspects of cognitive control, i.e. have participants actively engage with the musical tasks as well as the linguistic tasks. Further studies should continue to tap into the lesser studied area of lexical training and musical testing, while also incorporating tasks of cognitive control. Both behavioral and neuroimaging studies could illuminate more precise mechanisms and shared resources.

Implications of this work, should they continue to be replicated, have some potentially useful applications for foreign language curricula and instruction. Translation-ambiguity is common, and by aiding the learning of translation-ambiguous words and thereby expanding one's L2 vocabulary, communicative power will be tremendously increased. The musical interactions with language learning and potentially cognitive control should be motivational forces for students to continue learning languages and become proficient in a musical endeavor.

5.0 CONCLUSION

In conclusion, the present study examined translation-ambiguous world learning in terms of training frequency, musical ability, and musical experience. We found that translation-ambiguous words are recalled more accurately than unambiguous words, ambiguous words taught in the overtrained condition had greater recall, and that objective musical ability interacts with ability to learn translation-ambiguous words.

APPENDIX A

German	English 1	English 2	TSV	GWl	EWl1	EWl2	Efreq 1	Efreq 2
Untergehen	sink	decay	3.29	10.00	4.00	5.00	2.94	2.03
Erbschaft	heritage	inheritance	3.92	9.00	8.00	11.00	2.11	2.21
Himmel	heaven	sky	4.00	6.00	6.00	3.00	3.46	3.36
Sicherheit	safety	security	5.77	10.00	6.00	8.00	3.22	3.68
Geige	violin			5.00	6.00		2.39	
Zwang	force			5.00	5.00		3.56	
Bedarf	need			6.00	4.00		4.82	
Menschenmenge	crowd			13.00	5.00		3.28	
Gehäuse	case	housing	2.95	7.00	7.00	4.00	2.32	4.16
Vertrag	treaty	contract	4.67	7.00	6.00	8.00	2.38	3.22
Gerät	device	apparatus	5.31	5.00	6.00	9.00	2.97	1.89
Morgenrot	sunrise	dawn	5.50	9.00	7.00	4.00	2.49	3.11
Erdbeere	strawberry			8.00	10.00		2.45	
Zwilling	twin			8.00	4.00		2.73	
Anstecker	button			9.00	6.00		3.16	
Dorf	village			4.00	7.00		3.23	
Spannung	tension	suspense	4.55	8.00	7.00	8.00	2.64	2.06
Erzeugung	creation	production	4.92	9.00	8.00	10.00	2.49	2.81
Boden	floor	ground	5.86	5.00	5.00	6.00	3.71	3.57
Geschenk	gift	present	6.33	8.00	4.00	7.00	3.52	3.66
Betlaken	sheet			8.00	5.00		2.77	
Kaninchen	rabbit			9.00	6.00		3.03	
Knochen	bone			8.00	4.00		3.12	
Holz	wood			4.00	4.00		3.14	
Geschichte	history	story	3.86	10.00	7.00	5.00	3.63	4.05
Erinnerung	memory	reminder	4.29	10.00	6.00	8.00	3.39	2.29
Abbildung	picture	image	4.86	9.00	5.00	7.00	3.06	3.85
Glaube	belief	faith	5.80	6.00	6.00	5.00	2.59	3.37
Aufregung	excitement			9.00	10.00		2.80	
Genick	neck			6.00	4.00		3.48	
Wahrheit	truth			8.00	5.00		3.99	

Körper	body			6.00	4.00		4.00	
Grundlage	basis	reason	4.16	9.00	6.00	5.00	3.99	2.79
Gestalt	figure	shape	4.21	7.00	6.00	5.00	3.82	3.19
Nachricht	message	news	4.64	9.00	7.00	4.00	3.67	3.92
Gebiet	area	region	6.01	6.00	4.00	6.00	3.58	2.41
Müll	garbage			4.00	7.00		3.12	
Unschuld	innocence			8.00	9.00		2.53	
Ungerade	strange			8.00	7.00		3.64	
Streichen	paint			9.00	4.00		3.70	
Botschaft	message	embassy	2.00	9.00	7.00	7.00	2.60	3.67
Mieter	renter	tenant	5.21	6.00	6.00	6.00	1.15	2.19
Fehler	error	mistake	6.31	6.00	5.00	7.00	2.68	3.72
Menschen	people	humans	6.31	8.00	6.00	6.00	2.92	4.75
Möhre	carrot			5.00	6.00		2.29	
Wange	cheek			5.00	5.00		2.56	
Wahnsinn	insanity			8.00	8.00		2.59	
Winkel	angle			6.00	5.00		2.88	
Klatsch	rumor	gossip	5.40	7.00	5.00	6.00	2.73	2.60
Gegner	enemy	opponent	5.69	6.00	5.00	8.00	3.39	2.38
Vorschlag	proposal	suggestions	5.83	9.00	8.00	11.00	2.65	2.44
Folge	episode	result	2.43	5.00	7.00	6.00	2.80	3.00
Betrug	deceit			6.00	6.00		1.98	
Beschuldigung	accusation			13.00	10.00		2.16	
Pfeil	arrow			5.00	5.00		2.60	
Spalte	crack			6.00	5.00		3.22	
Kiefer	pine	jaw	1.25	6.00	4.00	3.00	2.50	2.56
Ursache	reason	cause	3.76	7.00	6.00	5.00	3.99	4.20
Schuld	guilt	fault	4.27	6.00	5.00	5.00	2.88	3.73
Trennung	breakup	separation	5.46	8.00	7.00	10.00	2.18	2.40
Vorteil	advantage			7.00	9.00		3.05	
Veranstaltung	event			13.00	5.00		3.13	
Baum	tree			4.00	4.00		3.52	
Aufmerksamkeit	attention			14.00	9.00		3.70	

APPENDIX B

1	I spend a lot of my free time doing music-related activities.
2	I sometimes choose music that can trigger shivers down my spine.
3	I enjoy writing about music, for example on blogs and forums.
4	If somebody starts singing a song I don't know, I can usually join in.
5	I am able to judge whether someone is a good singer or not.
6	I usually know when I'm hearing a song for the first time.
7	I can sing or play music from memory.
8	I'm intrigued by musical styles I'm not familiar with and want to find out more.
9	Pieces of music rarely evoke emotions for me.
10	I am able to hit the right notes when I sing along with a recording.
11	I find it difficult to spot mistakes in a performance of a song even if I know the tune.
12	I can compare and discuss differences between two performances or versions of the same piece of music.
13	I have trouble recognizing a familiar song when played in a different way or by a different performer.
14	I have never been complimented for my talents as a musical performer.
15	I often read or search the internet for things related to music.
16	I often pick certain music to motivate or excite me.
17	I am not able to sing in harmony when somebody is singing a familiar tune.
18	I can tell when people sing or play out of time with the beat.
19	I am able to identify what is special about a given musical piece.
20	I am able to identify what is special about a given musical piece.

21	I am able to talk about the emotions that a piece of music evokes for me.
22	I don't spend much of my disposable income on music. I can tell when people sing or play out of tune.
23	When I sing, I have no idea whether I'm in tune or not.
24	Music is kind of an addiction for me - I couldn't live without it.
25	I don't like singing in public because I'm afraid that I would sing wrong notes.
26	When I hear a piece of music I can usually identify its genre.
27	I would not consider myself a musician.
28	I keep track of new music that I come across (e.g. new artists or recordings).
29	After hearing a new song two or three times, I can usually sing it by myself.
30	I only need to hear a new tune once and I can sing it back hours later.
31	Music can evoke my memories of past people and places.
32	I engaged in regular, daily practice of a musical instrument (including voice) for ___ years
33	At the peak of my interest, I practiced ___ hours per day on my primary instrument.
34	I have attended ___ live music events as an audience member in the past twelve months.
35	I have had formal training in music theory for ___ years.
36	I have had ___ years of formal training on a musical instrument (including voice) during my lifetime.
37	I can play ___ musical instruments.
38	I listen attentively to music for ___ per day
39	The instrument I play best (including voice) is ___
40	I can read music

APPENDIX C

1	Participant Number
2	Age
3	Gender
4	Handedness Right Left
5	Native Country
6	Years spend in the U.S.
7	Do you have any known visual or hearing problems (corrected or uncorrected)?
8	What is your first language (i.e., **language first spoken**)? If more than one, please briefly describe the situations in which each language was used.
9	Which language (if any) do you consider your <u>second</u> language?
10	If you have ever lived in or visited a country where languages other than your native language are spoken, please indicate below the name of the country (countries), the duration of your stay in number of months, and which languages you used while you were in the country (please indicate if you were spoken to in a language other than your first language, even if you never actually spoke that language).
11	List below, from most fluent to least fluent, <u>all</u> of the languages to which you have been exposed. Also specify the age in years at which you began to learn the language and the context in which you learned it. For example, "English, birth, home". Include <u>all</u> languages to which you have been exposed, although you may never have had formal training in them and may not be able to read, speak or write them. **Please remember to list your native language(s).**
12	What languages were spoken in your home while you were a child and by whom?
14	How many years have you studied your second language? Please indicate the setting(s) in which you have had experience with the language (i.e., classroom, with friends, foreign country...)
15	Are you currently enrolled in any language courses? (Any course either instructed in a foreign language or designed to teach a foreign language). If so, please list the course number(s) below, along with the title of the course.
16	What languages **<u>other</u> than your first language** do you <u>speak</u> proficiently?
17	What languages **<u>other</u> than your first language** do you <u>read</u> proficiently?

18	What languages **<u>other</u> than your first language** do you <u>write</u> proficiently?
19	What languages **<u>other</u> than your first language** do you <u>understand</u> when they're spoken?
20	What languages do the following people speak? Mother Father Closest friend
21	** For the next eight questions, please check below the number of your response.**
22	Please rate your **first language** <u>reading</u> proficiency on a ten-point scale
23	Please rate your **second language** <u>reading</u> proficiency on a ten-point scale
24	Please rate your **first language** <u>writing</u> proficiency on a ten-point scale
25	Please rate your **second language** <u>writing</u> proficiency on a ten-point scale
26	Please rate your **first language** <u>conversational fluency</u> on a ten-point scale
27	Please rate your **second language** <u>conversational fluency</u> on a ten-point scale
28	Please rate your **first language** <u>speech comprehension ability</u> on a ten-point scale
29	Please rate your **second language** <u>speech comprehension ability</u> on a ten-point scale
30	How would you rate your foreign language learning skills? Please choose your response. Worse than Average Average Better than Average
31	When learning a new language, which of the following do you find the easiest to learn? Please rank the following from 1 to 4 (1=easiest; 4=hardest). Pronunciation Grammar Vocabulary Sayings / Expressions
32	Have you ever been immersed in your second language culture (please select)?
33	Please compare learning a second language in an immersion environment with one learning in a classroom environment (Which one is easier? In which did you learn more? ...) Please comment about the difference between your various learning experiences.
34	Is there anything else about your language background that you would like to comment on? Please feel free to make comments about things which were not covered on this questionnaire.
35	Education level *(<u>highest</u> level) FATHER (or, if applicable STEPFATHER or MALE*

	GUARDIAN) achieved/completed before you turned 18:
	Education level *(<u>highest</u> level) MOTHER (or, if applicable STEPMOTHER or FEMALE GUARDIAN) achieved/completed before you turned 18:*
36	Your education level *(<u>highest</u> level):*
37	What was your primary residence (address) during childhood?
38	Additional Information.

Note: For questions 21-28 participants responded on a 10-point Likert-like scale where 1 corresponded to not literate and 10 corresponded to literate.

APPENDIX D

Table 12. Fixed Effects for the Model for Free Recall with Ambiguity and Musical Ear Test: Rhythm as a Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-2.83	1.58	-1.79	0.07	.
German Length	-0.18	0.06	-2.93	0.00	**
English Avg. Length	-0.10	0.089	-1.11	0.27	
English Avg. Frequency	-0.23	0.25	-0.93	0.35	
English Avg. Concreteness	0.01	0.00	1.62	0.11	
TransAmbiguityAmbig: Musical Ear Test: Rhythm	4.90	1.58	3.09	0.00	**
TransAmbiguityUnambig: Musical Ear Test: Rhythm	4.15	1.57	2.64	0.01	**

Note: glmer(EntireAcc~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TransAmbiguity:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TransAmbiguity:METRhy || Participant),data=EleannaRecallData, family=binomial, glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. *p* < .10 * *p* < .05 ** *p* < .01 *** *p* < .001

Table 13 Fixed Effects for the Model for Free Recall with Ambiguity and Mowrer as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-1.21	1.22	-0.99	0.322	
German Length	-0.13	0.05	-2.50	0.01	*
English Avg. Length	-0.12	0.09	-1.39	0.16	
English Avg. Frequency	-0.27	0.25	-1.07	0.29	
English Avg. Concreteness	0.01	0.01	1.50	0.13	
TransAmbiguityAmbig: Mowrer	0.58	0.17	3.46	0.00	***
TransAmbiguityUnambig: Mowrer	0.45	0.16	2.75	0.01	**

Note: glmer(EntireAcc~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TransAmbiguity:Mowrer+(1|Participant)+(1|GermanWord)+(0 + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TransAmbiguity:Mowrer || Participant),data=EleannaRecallData, family=binomial, glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1000000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 14 Fixed Effects for the Model for Free Recall with Training Condition and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-2.450	1.97	-1.27	0.20	
German Length	-0.16	0.10	-1.58	0.11	
English Avg. Length	-0.27	0.15	-1.83	0.07	.
English Avg. Frequency	-0.19	0.33	-0.56	0.57	
English Avg. Concreteness	0.01	0.01	1.07	0.28	
TSV	0.07	0.12	0.58	0.56	
TrainingConditionOvertrained: Musical Ear Test: Melody	5.25	1.81	2.90	0.00	**
TrainingConditionStandard: Musical Ear Test: Melody	5.12	1.82	2.82	0.00	**

Note: glmer(BothTrans~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TSV+TrainingCondition:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TSV+TrainingCondition:METMel || Participant),data=EleannaRecallData.Ambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 15 Fixed Effects for the Model for Free Recall with Training Condition and Mowrer as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-0.780	1.66	-0.48	0.63	
German Length	-0.14	0.10	-1.45	0.15	
English Avg. Length	-0.28	0.14	-1.94	0.05	.
English Avg. Frequency	-0.21	0.34	-0.61	0.54	
English Avg. Concreteness	0.01	0.01	1.01	0.31	
TSV	0.068	0.12	0.57	0.57	
TrainingConditionOvertrained: Mowrer	0.62	0.21	2.97	0.00	**
TrainingConditionStandard: Mowrer	0.60	0.21	2.87	0.00	**

Note: glmer(BothTrans~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TSV+TrainingCondition:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+ EnglishAvLen + EnglishAvFreq + EnglishAvConc + TSV+TrainingCondition:Mowrer || Participant),data=EleannaRecallData.Ambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1000000)))

. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 16 Fixed Effects for the MET Rhythm Model Follow-up Overtrained Condition

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-4.51	2.21	-2.04	0.04	*
German Length	-0.18	0.11	-1.68	0.09	.
English Avg. Length	-0.14	0.14	-1.04	0.30	
English Avg. Frequency	0.25	0.33	0.74	0.46	
English Avg. Concreteness	0.01	0.01	0.74	0.46	
TSV	0.14	0.12	1.19	0.23	
Musical Ear Test: Rhythm	5.11	2.32	2.20	0.03	*

Note: glmer(BothTrans~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TSV+METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TSV+METRhy || Participant),data=EleannaRecallData.Overtrained, family=binomial,glmerControl(optimizer = “bobyqa", optCtrl = list(maxfun = 100000)))

. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 17 Fixed Effects for the MET Rhythm Model Follow-up Standard Condition

Fixed effect	β	SE	z value	Pr(>|z|)	
Intercept	-2.40	2.77	-0.87	0.39	
German Length	-0.21	0.14	-1.46	0.14	
English Avg. Length	-0.30	0.20	-1.51	0.13	
English Avg. Frequency	-0.51	0.45	-1.15	0.25	
English Avg. Concreteness	0.03	0.02	1.50	0.13	
TSV	0.01	0.16	0.07	0.94	
Musical Ear Test: Rhythm	6.60	2.53	2.61	0.01	**

Note: glmer(BothTrans~1+GermanLength+EnglishAvLen+EnglishAvFreq+EnglishAvConc+TSV+METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength + EnglishAvLen + EnglishAvFreq + EnglishAvConc + TSV+METRhy || Participant),data=EleannaRecallData.Standard, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 18 Fixed Effects for the Translation Recognition Accuracy Model with Ambiguity, Relatedness, and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	-2.07	1.47	-1.41	0.16	
German Length	-0.07	0.04	-1.79	0.07	.
English Length	-0.02	0.05	-0.45	0.65	
English Frequency	-0.02	0.14	-0.17	0.86	
English Concreteness	0.19	0.07	2.80	0.01	**
Translation Ambiguity-Ambiguous: relatedness- translation: Musical Ear Test: Rhythm	5.48	1.77	3.09	0.00	**
Translation Ambiguity-Unambiguous: relatedness-translation: Musical Ear Test: Rhythm	5.88	1.81	3.25	0.00	**
Translation Ambiguity-Ambiguous: relatedness-unrelated: Musical Ear Test: Rhythm	5.83	1.80	3.24	0.00	**
Translation Ambiguity-Unambig: relatedness-unrelated: Musical Ear Test: Rhythm	6.21	1.80	3.44	0.00	***

*Note:*glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METRhy ||

Participant),data=EleannaTRData.StdandUnambig, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 19 Fixed Effects for the Translation Recognition Accuracy Model with Ambiguity, Relatedness, and Mowrer as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	1.32	0.89	1.48	0.14	
German Length	-0.07	0.04	-1.81	0.07	.
English Length	-0.06	0.05	-1.21	0.23	
English Frequency	-0.02	0.14	-0.15	0.88	
English Concreteness	0.20	0.07	2.71	0.01	**
Translation Ambiguity-Ambiguous:					
relatedness-translation: Mowrer	0.21	0.18	1.17	0.24	
Translation Ambiguity-Unambiguity:					
relatedness-translation: Mowrer	0.29	0.17	1.78	0.08	.
Translation Ambiguity-Ambiguous:					
relatedness-unrelated: Mowrer	0.27	0.18	1.49	0.14	
Translation Ambiguity-Unambig:					
relatedness-unrelated: Mowrer	0.37	0.18	2.02	0.04	*

Note:
glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:Mowrer+(1|Participant)+(1|GermanWord)+(0+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:Mowrer || Participant),data=EleannaTRData.StdandUnambig, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 20 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition, Relatedness, and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	0.42	1.37	0.30	0.76	
German Length	-0.05	0.06	-0.82	0.41	
English Length	0.06	0.05	1.17	0.24	
English Frequency	-0.13	0.12	-1.09	0.28	
English Concreteness	0.13	0.08	1.68	0.09	.
TSV	0.02	0.01	1.36	0.17	
Training Condition-Standard	-0.34	0.86	-0.39	0.70	
Training Condition-Overtrained: Relatedness-translation:METMelody	1.54	1.73	0.89	0.37	
Training Condition-Standard: Relatedness-translation: Musical Ear Test: Melody	1.84	1.66	1.11	0.27	
Training Condition-Overtrained: Relatedness-unrelated: Musical Ear Test: Melody	1.29	1.71	0.76	0.45	
Training Condition-Standard: relatedness-unrelated: Musical Ear Test: Melody	2.01	1.65	1.22	0.22	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relat

edness:METMel || Participant),data=EleannaTransRecDataforR.Ambiguous,
family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
p < .10 * p < .05 ** p < .01 *** p < .001

Table 21 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition, Relatedness, and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	0.11	1.40	0.08	0.94	
German Length	-0.05	0.06	-0.80	0.43	
English Length	0.06	0.05	1.16	0.25	
English Frequency	-0.13	0.12	-1.08	0.28	
English Concreteness	0.13	0.08	1.66	0.10	.
TSV	0.02	0.01	1.35	0.18	
TrainingConditionStandard	-0.74	0.97	-0.76	0.45	
TrainingConditionOvertrained: relatednesstranslation:METRhythm	1.92	1.74	1.11	0.27	
TrainingConditionStandard: relatednesstranslation:METRhythm	2.80	1.68	1.66	0.10	.
TrainingConditionOvertrained: relatednessunrelated:METRhythm	1.71	1.72	1.00	0.32	
TrainingConditionStandard: relatednessunrelated:METRhythm	3.01	1.69	1.78	0.07	.

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:METRhy || Participant),data=EleannaTransRecDataforR.Ambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000))). p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 22 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition, Relatedness, and Goldsmiths Musical Sophistication Index as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	-7.66	9.70	-0.79	0.43	
German Length	-0.05	0.06	-0.86	0.39	
English Length	0.06	0.05	1.14	0.25	
English Frequency	-0.14	0.12	-1.11	0.27	
English Concreteness	0.13	0.08	1.67	0.10	.
TSV	0.02	0.01	1.36	0.17	
TrainingConditionStandard	4.13	6.99	0.59	0.55	
TrainingConditionOvertrained:relatednesstranslation: LG10GOLD	4.25	4.50	0.95	0.34	
TrainingConditionStandard:relatednesstranslation: LG10GOLD	2.27	4.29	0.53	0.60	
TrainingConditionOvertrained:relatednessunrelated: LG10GOLD	4.18	4.50	0.93	0.35	
TrainingConditionStandard:relatednessunrelated: LG10GOLD	2.33	4.29	0.54	0.59	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:LG10GOLD+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:LG10GOLD || Participant),data=EleannaTransRecDataforR.Ambiguous, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1000000))). p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 23 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition, Relatedness, and Mowrer as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	0.94	0.90	1.04	0.30	
German Length	-0.05	0.06	-0.85	0.39	
English Length	0.05	0.05	1.08	0.28	
English Frequency	-0.13	0.12	-1.04	0.30	
English Concreteness	0.13	0.08	1.71	0.09	.
TSV	0.02	0.01	1.38	0.17	
TrainingConditionStandard	0.20	0.39	0.51	0.61	
TrainingConditionOvertrained: relatednesstranslation: Mowrer	0.19	0.17	1.06	0.29	
TrainingConditionStandard: relatednesstranslation: Mowrer	0.06	0.17	0.34	0.73	
TrainingConditionOvertrained: relatednessunrelated: Mowrer	0.12	0.17	0.73	0.47	
TrainingConditionStandard: relatednessunrelated: Mowrer	0.12	0.17	0.69	0.49	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:Mowrer || Participant),data=EleannaTRData.relatedTAonly, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 24 Fixed Effects for the Translation Recognition Reaction Time Model with Ambiguity, Relatedness, and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	1962.26	499.37	60.91	3.93	0.00	***
German Length	54.90	18.17	54.91	3.02	0.00	**
English Length	8.08	14.16	1375.60	0.57	0.57	
English Frequency	-9.98	45.07	212.68	-0.22	0.82	
English Concreteness	-54.39	22.57	771.55	-2.41	0.02	*
Translation Ambiguity Ambiguous:relatedness-translation: Musical Ear Test Melody	-400.57	642.29	35.88	-0.62	0.54	
Translation Ambiguity-Unambiguous:relatedness-translation: Musical Ear Test Melody	-462.27	641.30	37.18	-0.72	0.48	
Translation Ambiguity-Ambiguous:relatedness-unrelated: Musical Ear Test Melody	-118.01	648.13	34.50	-0.18	0.86	
Translation Ambiguity-Unambiguous:relatedness-unrelated: Musical Ear Test Melody	-253.64	641.79	37.52	-0.40	0.69	

*Note:*lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METMel || Participant),data=EleannaTRData,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 25 Fixed Effects for the Translation Recognition Reaction Time Model with Ambiguity, Relatedness, and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	749.18	661.42	27.94	1.13	0.27	
German Length	53.28	14.19	70.20	3.76	0.00	***
English Length	7.54	14.19	1370.89	0.53	0.60	
English Frequency	-12.68	46.53	100.33	-0.27	0.79	
English Concreteness	-50.59	22.65	767.04	-2.23	0.03	*
Translation Ambiguity-Ambiguous:relatedness-translation: Musical Ear Test Rhythm	1360.07	905.58	21.21	1.50	0.15	
Translation Ambiguity-Unambiguous:relatedness-translation: Musical Ear Test Rhythm	1269.67	905.44	20.94	1.40	0.18	
Translation Ambiguity-Ambiguous:relatedness-unrelated: Musical Ear Test Rhythm	1635.69	916.44	21.97	1.79	0.09	.
Translation Ambiguity-Unambiguous:relatedness-unrelated: Musical Ear Test Rhythm	1460.97	900.37	20.69	1.62	0.12	

*Note:*lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:METRhy+(1|Participant)+(1|GermanWord)+(0 +EngFreq+EngConc+TransAmbig:relatedness:METRhy || Participant),data=EleannaTRData,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

$p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 26 Fixed Effects for the Translation Recognition Reaction Time Model with Ambiguity, Relatedness, and Mowrer as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	1970.37	308.11	189.95	6.40	0.00	***
German Length	55.06	17.96	48.52	3.07	0.00	**
English Length	8.00	14.16	1371.20	0.57	0.57	
English Frequency	-9.04	44.99	182.87	-0.20	0.84	
English Concreteness	-54.23	22.49	765.78	-2.41	0.02	*
Translation Ambiguity-Ambiguous:relatedness-translation: Mowrer	-87.90	67.41	37.68	-1.30	0.20	
Translation Ambiguity-Unambiguous:relatedness-translation: Mowrer	-106.14	66.94	38.79	-1.59	0.12	
Translation Ambiguity-Ambiguous:relatedness-unrelated: Mowrer	-34.16	69.90	33.68	-0.49	0.63	
Translation Ambiguity-Unambiguous:relatedness-unrelated: Mowrer	-57.61	67.35	32.78	-0.86	0.40	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TransAmbig:relatedness:Mowrer || Participant),data=EleannaTRData,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 27 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition, Relatedness, and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	2293.73	754.19	38.55	3.04	0.00	**
German Length	65.61	28.36	32.52	2.31	0.03	*
English Length	3.43	20.64	75.20	0.17	0.87	
English Frequency	-21.91	54.16	110.54	-0.40	0.69	
English Concreteness	-17.42	31.45	502.40	-0.55	0.58	
TSV	-0.98	4.67	29.28	-0.21	0.83	
TrainingConditionStandard	150.90	396.80	41.40	0.38	0.71	
TrainingConditionOvertrained:relatednesstranslation: Musical Ear Test Melody	-1097.62	999.79	25.26	-1.10	0.28	
TrainingConditionStandard:relatednesstranslation: Musical Ear Test Melody	-1223.78	915.81	31.00	-1.34	0.19	
TrainingConditionOvertrained:relatednessunrelated: Musical Ear Test Melody	-769.38	1008.61	24.85	-0.76	0.45	
TrainingConditionStandard:relatednessunrelated: Musical Ear Test Melody	-992.19	918.79	29.93	-1.08	0.29	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:METMel || Participant),data=EleannaTransRecDataforR.Ambiguous,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 28 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition, Relatedness, and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	907.47	787.09	41.88	1.15	0.26	
German Length	65.32	28.63	36.12	2.28	0.03	*
English Length	4.07	19.91	93.81	0.20	0.84	
English Frequency	-19.75	51.65	785.66	-0.38	0.70	
Engglish Concreteness	-17.32	31.43	494.14	-0.55	0.58	
TSV	-1.17	4.62	29.33	-0.25	0.80	
TrainingConditionStandard	-77.22	433.23	48.54	-0.18	0.86	
TrainingConditionOvertrained:relatednesstranslation:						
Musical Ear Test Rhythm	878.10	1034.02	28.02	0.85	0.40	
TrainingConditionStandard:relatednesstranslation:						
Musical Ear Test Rhythm	1087.59	919.13	37.03	1.18	0.24	
TrainingConditionOvertrained:relatednessunrelated:						
Musical Ear Test Rhythm	1210.34	1041.53	27.58	1.16	0.26	
TrainingConditionStandard:relatednessunrelated:						
Musical Ear Test Rhythm	1321.73	921.99	36.04	1.43	0.16	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:METRhy || Participant),data=EleannaTransRecDataforR.Ambiguous,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1000000))). p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 29 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition, Relatedness, and Goldsmiths Musical Sophistication Index as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	9553.91	5509.77	23.03	1.73	0.10	.
German Length	65.42	29.01	36.06	2.26	0.03	*
English Length	3.57	19.86	98.51	0.18	0.86	
English Frequency	-21.40	52.43	153.63	-0.41	0.68	
English Concreteness	-18.53	31.47	502.92	-0.59	0.56	
TSV	-1.08	4.66	29.35	-0.23	0.82	
TrainingConditionStandard	-2020.57	3289.57	40.21	-0.61	0.54	
TrainingConditionOvertrained:relatednesstranslation: LG10GOLD	-3724.60	2553.24	22.91	-1.46	0.16	
TrainingConditionStandard:relatednesstranslation: LG10GOLD	-2754.98	2319.84	32.14	-1.19	0.24	
TrainingConditionOvertrained:relatednessunrelated: LG10GOLD	-3614.61	2554.18	22.94	-1.42	0.17	
TrainingConditionStandard:relatednessunrelated: LG10GOLD	-2674.59	2320.08	32.16	-1.15	0.26	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+Training Condition+TrainingCondition:relatedness:LG10GOLD+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:LG10GOLD || Participant),data=EleannaTransRecDataforR.Ambiguous,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 30 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition, Relatedness, and Mowrer as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	2116.15	437.43	108.24	4.84	0.00	***
German Length	67.49	28.58	34.63	2.36	0.02	*
English Length	3.50	20.58	78.36	0.17	0.87	
English Frequency	-16.57	53.46	109.98	-0.31	0.76	
English Concreteness	-19.11	31.43	495.38	-0.61	0.54	
TSV	-0.51	4.62	29.36	-0.11	0.91	
TrainingConditionStandard	-229.71	172.30	266.26	-1.33	0.18	
TrainingConditionOvertrained:relatednesstranslation: Mowrer	-193.30	97.90	38.43	-1.98	0.06	.
TrainingConditionStandard:relatednesstranslation: Mowrer	-98.16	95.06	33.32	-1.03	0.31	
TrainingConditionOvertrained:relatednessunrelated: Mowrer	-127.86	99.97	39.25	-1.28	0.21	
TrainingConditionStandard:relatednessunrelated: Mowrer	-52.75	95.36	30.80	-0.55	0.58	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:relatedness:Mowrer || Participant),data=EleannaTransRecDataforR.Ambiguous, control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 31 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	2.14	1.90	1.13	0.26	
German Length	0.00	0.07	0.02	0.99	
English Length	-0.07	0.08	-0.89	0.37	
English Frequency	-0.17	0.19	-0.90	0.37	
English Concreteness	0.19	0.11	1.70	0.09	.
TSV	0.05	0.02	2.17	0.03	*
TrainingConditionStandard	-0.01	1.20	-0.01	0.99	
TrainingConditionOvertrained: Musical Ear Test Melody	-1.04	2.45	-0.43	0.67	
TrainingConditionStandard: Musical Ear Test Melody	-1.23	2.26	-0.54	0.59	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+ TrainingCondition:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:METMel || Participant),data=EleannaTRData.relatedTAonly, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
p < .10 * p < .05 ** p < .01 *** p < .001

Table 32 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition and Musical Ear Test: Rhythm as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	0.03	2.06	0.02	0.99	
German Length	0.00	0.07	0.04	0.97	
English Length	-0.06	0.08	-0.83	0.41	
English Frequency	-0.18	0.19	-0.92	0.36	
English Concreteness	0.19	0.11	1.69	0.09	.
TSV	0.04	0.02	2.07	0.04	*
TrainingConditionStandard	0.17	1.41	0.12	0.90	
TrainingConditionOvertrained: Musical Ear Test Rhythm	2.09	2.69	0.78	0.44	
TrainingConditionStandard: Musical Ear Test Rhythm	1.63	2.46	0.66	0.51	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:METRhy+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:METRhy || Participant),data=EleannaTRData.relatedTAonly, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 33 Fixed Effects for the Translation Recognition Accuracy Model with Training Condition and Goldsmiths Musical Sophistication Index as Fixed Effects

Fixed effect	β	SE	z value	Pr(>|z|)	
(Intercept)	-14.30	12.71	-1.13	0.26	
German Length	0.00	0.07	0.04	0.97	
English Length	-0.07	0.08	-0.85	0.40	
English Frequency	-0.18	0.19	-0.96	0.34	
English Concreteness	0.19	0.11	1.70	0.09	.
TSV	0.04	0.02	2.08	0.04	*
TrainingConditionStandard	8.76	8.91	0.98	0.33	
TrainingConditionOvertrained: LG10GOLD	7.34	5.91	1.24	0.21	
TrainingConditionStandard: LG10GOLD	3.19	5.58	0.57	0.57	

Note: glmer(TransRecAcc~1+GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:LG10GOLD+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:LG10GOLD || Participant),data=EleannaTRData.relatedTAonly, family=binomial,glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 34 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition and Musical Ear Test: Melody as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	1996.83	795.03	65.52	2.51	0.01	*
German Length	59.71	37.68	37.00	1.59	0.12	
English Length	23.13	31.69	161.46	0.73	0.47	
English Frequency	-44.92	85.79	110.28	-0.52	0.60	
English Concreteness	-104.40	51.78	52.65	-2.02	0.05	*
TSV	-7.22	6.12	29.27	-1.18	0.25	
TrainingConditionStandard	753.31	539.27	22.14	1.40	0.18	
TrainingConditionOvertrained: Musical Ear Test Melody	-143.43	976.66	38.95	-0.15	0.88	
TrainingConditionStandard: Musical Ear Test Melody	-1123.70	916.05	40.96	-1.23	0.23	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+ TrainingCondition:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:METMel || Participant),data=EleannaTRData.relatedTAonly,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))
. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 35 Fixed Effects for the Translation Recognition Reaction Time Model with Training Condition and Goldsmiths Musical Sophistication Index as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	8917.32	5691.84	38.52	1.57	0.13	
German Length	60.98	37.39	36.55	1.63	0.11	
English Length	23.81	31.65	159.20	0.75	0.45	
English Frequency	-40.38	85.65	108.88	-0.47	0.64	
English Concreteness	-103.23	51.60	52.11	-2.00	0.05	.
TSV	-7.05	6.09	29.14	-1.16	0.26	
TrainingConditionStandard	-857.21	4633.37	21.95	-0.19	0.85	
TrainingConditionOvertrained: LG10GOLD	-3273.69	2637.45	38.32	-1.24	0.22	
TrainingConditionStandard: LG10GOLD	-2839.58	2492.49	35.22	-1.14	0.26	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+ TrainingCondition:LG10GOLD+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:LG10GOLD || Participant),data=EleannaTRData.relatedTAonly,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. p < *.10* * p < *.05* ** p < *.01* *** p < *.001*

Table 36 Fixed Effects for the Translation Recognition Reaction Time Model 25 with Training Condition and Mowrer as Fixed Effects

Fixed effect	β	SE	df	t value	Pr(>|t|)	
(Intercept)	2010.96	530.81	89.21	3.79	0.00	***
German Length	61.44	37.31	36.61	1.65	0.11	
English Length	24.10	31.58	157.10	0.76	0.45	
English Frequency	-41.25	85.40	107.54	-0.48	0.63	
English Concreteness	-102.86	51.36	51.62	-2.00	0.05	.
TSV	-7.17	6.05	29.11	-1.19	0.25	
TrainingConditionStandard	20.75	239.14	107.57	0.09	0.93	
TrainingConditionOvertrained: Mowrer	-48.44	97.11	44.80	-0.50	0.62	
TrainingConditionStandard: Mowrer	-28.95	96.99	36.75	-0.30	0.77	

Note: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TSV+ TrainingCondition+TrainingCondition:Mowrer+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TSV+TrainingCondition+TrainingCondition:Mowrer || Participant),data=EleannaTRData.relatedTAonly,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

. $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

APPENDIX E

Table 37. Musical Ability and Experience Task Correlations

		Musical Ear Test: Melody	Musical Ear Test: Rhythm	Mowrer	Goldsmiths Musical Sophistication Index
Musical Ear Test: Melody	Pearson Correlation	1	.696**	.821**	.440**
	Sig. (2-tailed)		0	0	0.009
	N	34	34	34	34
Musical Ear Test: Rhythm	Pearson Correlation	.696**	1	.659**	.464**
	Sig. (2-tailed)	0		0	0.006
	N	34	34	34	34
Mowrer	Pearson Correlation	.821**	.659**	1	.488**
	Sig. (2-tailed)	0	0		0.003
	N	34	34	34	34
Goldsmiths Musical Sophistication Index	Pearson Correlation	.440**	.464**	.488**	1
	Sig. (2-tailed)	0.009	0.006	0.003	
	N	34	34	34	34

Note: **Correlation is significant at the 0.01 level (2-tailed).

FOOTNOTES

1. We had significant difficulties getting models that included Gold-MSI to converge, even after transforming it. When the models did converge, the models that included this variable rarely had the lowest AIC. Therefore, none of these variables are discussed in the main text. In the future, we will continue to explore these data, seeking possible additional transformations or examining subscales of the scale to determine whether these may lead to better convergence.

2. As stated here, one of our goals was to examine translation ambiguity effects. However, to improve model convergence, we did not include the main effect of translation ambiguity in the models and instead examined this issue through its interaction with musical ability measures, given that interactions of this variable would qualify its main effects. However, in the one instance in which there was no interaction of translation ambiguity with musical ability, we ran an additional model that did include the main effect of translation ambiguity and found no effect of translation ambiguity. Specific model run: lmer(TransRecRTtrim~1+GermanLength+EngLen+EngFreq+EngConc+TransAmbig+relatedness:METMel+(1|Participant)+(1|GermanWord)+(0 + GermanLength+EngLen+EngFreq+EngConc+TransAmbig+relatedness:METMel || Participant),data=EleannaTRData,control=lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 100000)))

REFERENCES

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, *68*(3), 255-278.

Bracken, J., Degani, T., Eddington, C., & Tokowicz, N. (2017). Translation semantic variability: How semantic relatedness affects learning of translation-ambiguous words. *Bilingualism: Language and Cognition, 20*(4), 783-794. doi: 10.1017/S1366728916000274

Brysbaert, M., & New, B. (2009). Moving beyond Kucera and Francis: a critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. Behavioral Research Methods, 41(4), 977-990. doi: 10.3758/BRM.41.4.977

Degani, T., & Tokowicz, N, (2010). Ambiguous words are harder to learn. *Bilingualism: Language and Cognition, 13,* 299-314.

Degani, T., Tseng, A., & Tokowicz, N. (2014). Together or apart: Learning of translation-ambiguous words. *Bilingualism: Language and Cognition, 17*, 749-765. doi:10.1017/S1366728913000837

DeLosh, E. L., & McDaniel, M. A. (1996). The role of order information in free recall: Application to the word- frequency effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 1136–1146.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135-168. doi:10.1146/annurev-psych-113011-143750

Eddington, C. M., & Tokowicz, N. (2013). Examining English-German translation ambiguity using primed translation recognition. *Bilingualism: Language and Cognition, 16,* 442-457

Ellis, Rod. (2004). Individual Differences in Second Language Learning. In A. Davies & C. Elder (Eds.), *The Handbook of Applied Linguistics* (pp. 525-552). Oxford, UK: Blackwell Publishing.

Flege, J. E., Frieda, E. M., & Nozawa, T. (1997). Amount of native-language (L1) use affects the pronunciation of an L2. *Journal of Phonetics, 25*(2), 169-186. doi:10.1006/jpho.1996.0040

Kunert R. and Slevc L. R. (2015) A Commentary on: *"Neural overlap in processing music and speech"*. Front. Hum. Neurosci. 9:330. doi: 10.3389/fnhum.2015.00330

Kuznetsova, A., Brockhoff, P.B., & Christensen, R.H.B. (2013). lmerTest: Testsfor random and fixed effects for linear mixed effects models (lmer objects of lme4package). R package version 2.0-3. 2013. Available from: <https://CRAN.R-project.org/package=lmerTest>

Kroll, J. F., & Tokowicz, N. (2001). The development of conceptual representation for words in a second language. In J. L. Nicol (Ed.), *One mind, two languages: Bilingual language processing* (pp. 49-71). Malden, MA: Blackwell Publishers.

Narzikul, K., Tolentino, L. C., & Tokowicz, N. (2015, October). *Second language learning and musical ability: An ERP study.* Poster presented at the 55th Annual Meeting of the Society for Psychophysiological Research, Seattle, WA.

Norris, C. E. (2000). *Factors related to the validity of reproduction tonal memory tests.* Journal of Research in Music Education, 48(1), 52-64. doi:10.2307/3345456

Masataka, N., & Perlovsky, L. (2013). Cognitive interference can be mitigated by consonant music and facilitated by dissonant music. Scientific Reports, 3, 1-6.

Mowrer, T. A. (1996). *Tonal Memory As An Audition Factor For Choral Ensembles* (Doctoral dissertation). Retrieved from ProQuest. (Order No. 9632078)

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). The Musicality of Non-Musicians: An Index for Assessing Musical Sophistication in the General Population. *PLoS ONE, 9*(2). doi:10.1371/journal.pone.0089642

Okada, B. M., & Slevc, L. R. (2018). Individual differences in musical training and executive functions: A latent variable approach. *Memory & Cognition, 46*(7), 1076-1092. doi:10.3758/s13421-018-0822-8

Okada, B. M., & Slevc, L. R. (In Press). Musical training: Contributions to executive function. In M.Bunting, J. Novick, M. Dougherty, & R. W. Engle (Eds.), *An Integrative Approach to Cognitive and Working Memory Training: Perspectives from Psychology, Neuroscience, and Human Development*. New York, NY: Oxford University Press.

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106*, 15583-15587.

Patel, A. D. (2003). Language, music, syntax and the brain. *Nature Neuroscience, 6,* 674-681. doi:10.1038/nn1082

Perruchet, P., & Poulin-Charronnat, B. (2013). Challenging prior evidence for a shared syntactic processor for language and music. *Psychonomic Bulletin and Review, 20*(2), 310-317.

Slevc, L. R., Davey, N. S., Buschkuehl, M., & Jaeggi, S. M. (2016). Tuning the mind: Exploring the connections between musical ability and Executive Functions. *Cognition, 152,* 199-211.

Published in final form at: http://dx.doi.org//10.1016/j.cognition.2016.03.017

Slevc, R., & Miyake, A. (2006). Individual differences in second-language proficiency: Does musical ability matter? *Psychological Science*, *17*(8), 675–681. https://doi.org/10.1111/j.1467-9280.2006.01765.x

Slevc, R., & Okada, B. (2015). Processing structure in language and music: A case for shared reliance on cognitive control. *Psychonomic Bulletin & Review, 22*(3), 637-652. doi:10.3758/s13423-014-0712-4

Slevc, L. R., Reitman, J. G., & Okada, B. M. (2013). Syntax in music and language: The role of cognitive control. Proceedings of the 35th Annual Conference of the Cognitive Science Society (pp. 3414- 3419). Berlin, Germany: Cognitive Science Society.

Slevc, L. R., Rosenberg, J. C., & Patel, A. D. (2009). Making psycholinguistics musical: Self-paced reading time evidence for shared processing of linguistic and musical syntax. Psychonomic Bulletin and Review, 16(2), 374-381. doi:10.3758/16.2.374

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology 18* (6): 643-662.

RStudio Team (2016). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA <https://www.rstudio.com/>

Terrazas, G. (2018). Alleviating the translation-ambiguity disadvantage: Using a placeholder to signal an upcoming translation (Unpublished master's **thesis**). University of Pittsburgh, Pittsburgh, PA.

Tokowicz, Natasha. 2014. Translation Ambiguity Affects Language Processing, Learning, and Representation. In *Selected Proceedings of the 2012 Second Language Research Forum*, ed. Ryan T. Miller et al., 170-180. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #3095.

Tokowicz, N., B. Michael E. B., & Kroll, J. (2004). The Roles of Study-Abroad Experience and Working-Memory Capacity in the Types of Errors Made during Translation. *Bilingualism: Language and Cognition*. 7. 10.1017/S1366728904001634.

Tolentino, L. C., & Tokowicz, N. (2014). Cross-Language Similarity Modulates Effectiveness of Second Language Grammar Instruction. *Language Learning*, *64*(2), 279–309. https://doi.org/10.1111/lang.12048

Wallentin, M., Nielsen, A. H., Friis-Olivarius, M., Vuust, C., & Vuust, P. (2010). The Musical Ear Test, a new reliable test for measuring musical competence. *Learning and Individual Differences*, *20*(3), 188-196. doi:10.1016/j.lindif.2010.02.004

Wing, H.D. (1968). *Tests of musical ability and appreciation: An investigation into the measurement, distribution, and development of musical capacity* (2nd ed.). London: Cambridge University Press.