Issues of literacy, issues of modality: Language evolution from a cultural perspective

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Abstract

Recent research has identified a systematicity bias in human language. That is, humans show a cognitive bias towards compositionality in language. It has previously been suggested that literacy may prompt or enhance this bias in learners. This dissertation presents the results of an experiment which aimed to isolate possible literacy effects of this systematicity bias, using a musical language paradigm. Results indicate that literacy alone may not be sufficient for the development of this systematicity bias. However, differences between musical and orthographical literacy were identified, and may have contributed to these results. A further experiment attempted to address the validity of using such a musical language paradigm, and results indicated that referential meaning is indeed relevant for artificial language learning. Thus, the validity of this paradigm may fall under question, and so, researchers must be cautious to consider both literacy and referential meaning when employing such a paradigm.

Contents

1. Introduction

The evolution of language has been proposed to be dependent upon three factors: biological evolution, cultural evolution, and individual learning (Kirby & Hurford 2002), and the interactions between the three. Biological evolution includes the evolution of the learning and processing mechanisms which humans use for language, and how these adapt in response to selection pressures in the environment. Individual learning facilitates adaptation of our linguistic knowledge in response to our linguistic environment, in order to produce and process language accurately and appropriately. It is cultural evolution which is the focus of this dissertation. Cultural transmission of language (e.g. from peer to peer, parent to child, teachers to learners etc) can lead to cultural evolution of the linguistic system, due to the action of pressures during transmission. Cultural evolution may account for the seemingly "designed" aspects of language, such as the systematicity bias observed in humans (Smith 2006). Systematicity bias refers to a cognitive bias towards the learning and reproducing of compositional patterns in language.– i.e. learners are sensitive to systematic regularities in their input, and readily reproduce this systematicity. Thus, this is a worthwhile avenue of investigation in linguistics.

Previous work into cultural language evolution has suggested that literacy may enhance this systematicity bias, allowing it to flourish in a population (Brown 2008, Kirby Cornish & Smith 2008). However, these studies did not control for literacy effects – participants were literate individuals, and in Kirby Cornish and Smith were presented with textual stimuli in an artificial language learning paradigm. Thus, literacy effects should be isolated, in order to illuminate the effect of this learned skill upon the development of systematicity bias.

It is hypothesised that literacy will be shown to have a profound effect upon the development of systematicity bias, as a facet of metalinguistic awareness.

Thus, a musical language paradigm will be used, in order to model natural language. In this paper, so-called "illiterate" musicians – those who play and practice regularly, but do not read musical notation – will be taught a musical language, which is split into three levels of compositionality. It is hypothesised that these illiterate musicians will behave like non-musicians from a previous study by Brown (2008), who tested both musicians and non-musicians on a musical language. Musicians were found to have imposed higher compositionality on their output languages than non-musicians. If the "illiterate" musicians studied in this paper perform like the musicians in Brown's study (noting and replicating compositionality in the languages), we can conclude that literacy alone is not sufficient to supply the musicians with systematicity bias. If, however, the "illiterates" perform like the non-musicians then we may conclude that it is literacy which allows the musician to become aware of compositionality and structure in the musical languages. This may cast light upon orthographic literacy and metalinguistic knowledge.

The role of meaning in language is an important one. Languages are, by definition, referential. However, is referential meaning needed in order to learn an artificial language? As was highlighted by Brown (2008: 51), even musicians are "not accustomed to pairing referential content to musical sequences". This is because musical excerpts do not carry referential or propositional meaning. However, language, unlike music, does commonly carry referential meaning. Thus, this allows us a mode of comparison[1] not available in natural language – a language which carries referential meaning compared with one which does not.

It is hypothesised that referential meaning is irrelevant to learning an artificial language, and, thus, that it is valid to use a musical (non-referential0 language as a model for natural language.

Thus, an experiment is useful here. Orthographically literate participants will be trained on a spoken language, with three levels of compositionality, and their results compared with the results from the musicians trained on a musical language, from Brown's 2008 paper. If our orthographical participants notice and learn the regularity of the spoken language to the same degree as the musicians did the musical one, then we may conclude that a non-referential language is just as readily learnt as referential

[1] In further discussion of this comparison, "modality" will be used to refer to the two conditions – referential and non-referential.

one, in an artificial language learning experiment. Thus, a musical language is justified as a model for natural language. However, if our participants notice and learn the regularity of the spoken language to a greater degree than the musical one then referential meaning is not easily transferred to different modalities. Thus, the validity of using a musical language as a model will be addressed.

1.1. Studies

This dissertation will present the results of two studies – the first exploring literacy, and the second exploring the role of modality.

The first experiment to be presented will replicate Brown's 2008 musical languages, with so-called "illiterate" musicians. These participants will be exposed to three musical languages, each with differing compositionality levels. "Compositionality" means that the meaning of a signal is a function of the meaning of its parts, and the way in which these are combined. Three languages will be taught to the participants, one with full compositionality, one fully random, and another largely compositional, but with some exceptions. The performance of these illiterate musicians will be compared to the performance of Brown's musicians and non-musicians, in order to address whether literacy does indeed enhance or facilitate systematicity bias. Alternatively, literacy may prove unimportant, in which case practice in, or exposure to, language may be presumed relevant to the development of systematicity bias.

The second experiment uses a spoken language to test whether referentiality of meaning is relevant for learning artificial languages. The spoken languages will mirror Brown's 2008 musical languages, each having three different levels of compositionality. The performance of the participants in this spoken language will be compared with the performance of Brown's musicians, in order to address possible modality effects. Is referential meaning crucial to artificial language learning, or can non-referential artificial languages be learnt to a similar degree as referential ones?

2. Background to the dissertation
Evidence for systematicity bias in humans

2.1 Cumulative cultural evolution

Language is a prime example of cumulative cultural evolution. Cumulative cultural evolution refers to a particular kind of social learning, in which modifications accumulate over time, causing successive improvements in performance over generations of learning (Caldwell & Millen 2008: 3529). Boyd and Richerson have shown that social learning can increase a population's fitness, if this social learning allows "learned improvements to accumulate from one generation to the next" (1994: 134). Tomasello coined the term "ratchet effect", which he claims acts to keep the new, improved form of practice faithfully preserved, without slipping back to a less efficient form of practice (1999: 5). Cumulative cultural evolution is evident throughout human society – language, technology, and complex behaviours, are all results of this action. One clear example given by Caldwell and Millen (2008) is that of the wheel. First invented between 5,000 and 6,000 years ago, it has undergone almost continuous modification, and indeed exaptation (e.g. cogs and pulleys). However, this kind of cultural evolution is not evident in other animals. Although social learning is seen in, for example, Japanese macaques, (Horner et al 2006, Kawai 1965, Kawamura 1959), these tend to be simple behaviours, which are readily learnable by individual trial and error. However, whilst there remains some controversy over whether cumulative cultural evolution really is uniquely human (see Boyd and Richerson 1996, Galef Jr. 1992), that discussion is outside the scope of this paper.

Mechanisms for cultural evolution may aid us in pinpointing how and why cultural evolution changes language. Theories focusing on cultural transmission may be split into two categories, 1) bottlenecked transmission, and 2) biased transmission (Smith 2006). Bottlenecked transmission occurs when a bottleneck is in place in a language, over successive generations of transmission. This is seen in natural language, as although humans are capable of expressing, through language, an infinite array of concepts, no human will ever come across every possible linguistic expression. Thus, a bottleneck imposes pressure on the language to become compositional and recursive –i.e. more easily learnt. This pressure leads to languages which have a regular and generalisable structure, which is "preserved in the mapping between semantics and strings" (Kirby 2002: 199). Compositional systems such as these are stable, whilst non-compositional systems are unstable, over cultural time (Smith 2006). Thus, languages evolve through cultural time and bottlenecked transmission to become more and more regular and generalisable, due to pressure for compositionality.

The second category into which theories of cultural transmission can fall is that of language evolution as a consequence of learning biases in individual learners and learner groups. This theory argues that the most easily-learnt linguistic devices will flourish in languages, while less easily-learnt ones will disappear. This results in a learner bias towards easily-learnt devices and operations, which, through cultural time, leads to languages becoming increasingly compositional. This is an example of cumulative cultural evolution, in that learned improvements increase over successive cultural generations. Compositionality allows us to generalise to unseen items, as the system is regular. Thus compositionality makes languages not only more stable, but also more easily learnt.

2.1.1. Theoretical and Computer Modelling approaches

We will now discuss differing approaches to studying cultural evolution in language. Recent approaches include theoretical and computer modelling. In particular, iterated learning paradigms have been used extensively (see Batali 1998, Kirby 1999, Kirby & Hurford 2002, Smith 2002, Brighton 2002, Griffiths & Kalish 2007). Iterated learning paradigms consist of chains of transmission. Each agent (in this case, a simulated individual) must acquire a language subset, by observing the behaviour of a prior agent (teacher). Once the agent has acquired the language subset, it becomes the teacher, and so on for successive generations. Kirby and Hurford (2002), using an iterated learning paradigm, found that language becomes easier to learn, as it adapts to the learning algorithm in place by becoming increasingly structured. Thus, pressures in transmission cause language to adapt. Kirby, Dowman and Griffiths (2007) have shown that "cultural transmission can magnify weak biases into strong linguistic universals" (5241). In other words, it may be the case that language learning is not guided by strong innate constraints, rather, weak biases are transformed, through cumulative cultural evolution, to strong universals, operating at a population level. Furthermore, Smith, Brighton and Kirby (2003) showed that poverty of the stimulus leads to a pressure for structure in language. As we are exposed to an impoverished input (i.e. we will never hear all of the possible sentences in the language), we must be able to generalise from systematic rules to material we have not encountered. Thus, a pressure for structure in language leads to compositionality, which can emerge from an initially non-compositional system through cumulative cultural evolution.

Smith (2004) has shown, through mathematical modelling, that learning biases can cause the evolution of maximally transparent linguistic systems. In other words, a bias towards languages which consist of a regular, one-to-one mapping between signal and meaning, and a perfectly systematic underlying system, will eventually result in a language with these features, i.e. a "communicatively optimal…system" (Smith 2004: 127). Thus, computational and mathematical modelling has proven that language is a complex adaptive system which adapts to become easier to learn, and that is does so by becoming more structured.

2.1.2. Laboratory Studies

Laboratory studies of cumulative cultural evolution have been reinvigorated in recent years, and provide a second avenue of investigation into cultural evolution (see Mesoudi & Whiten 2008 for a discussion). Iterated learning experiments have proven that, over extended iterations, behaviours tend to become more easily learned and structured. These experiments reflect the behaviour of social practices in reality. Language, an outcome of iterated learning, shows these features. Kirby, Cornish and Smith (2008) used an iterated learning model with human learners, and found that iterated learning and cumulative culture leads learners to impose structure onto languages. Furthermore, highly systematic languages were learned and reproduced to a greater degree and with greater fidelity than random ones – languages towards the end of transmission chains were more faithfully reproduced than ones early in the chain of transmission. This is evidence of a systematicity bias in humans. Additionally, it was found that found that languages do indeed evolve to become more "learnable", by becoming more structured – the authors tracked the evolution of a language, through successive generations, from an initially random state to a language showing adaptive structure. Thus, cultural language evolution is seen here, as a change in a linguistic system as a result of cultural transmission. The experiment consisted of two conditions. In the first, each participant's output automatically became the input for the next generation, with no filtering. In this case, the languages which emerged at the end of transmission chains were characterised by underspecification – some meanings were ambiguous. In the second condition, each participant's output was filtered of all underspecification. This was introduced as an analogue of the pressure to be expressive. In this case, languages evolved to have regularity and systematicity in signal-meaning mappings. Each signal could be analysed as separate morphemes with individual meanings, with only occasional irregularities (mirroring natural language). Thus, it has been proven that language can adapt to constraints on learning, over cultural time, through iterated learning. In a further analysis of the data discussed in this paper, Cornish, Tamaríz and Kirby (In press) used *RegMap*[2], a measurement of compositionality in language, in order to explore the behaviour of individual segments. They noted that individual signals come to encode individual meanings, while the whole system evolves to avoid underspecification or ambiguity (Cornish, Tamaríz & Kirby: In press, 10). Additionally, the role of the bottleneck was investigated, and it was found to amplify the systematicity found in smaller sub-sets of the language, through successive iterations. Thus, patterns which appear weak come to appear stronger with repeated iterations.

2.1.3. Compositionality in artificial language experiments

Tamariz and Smith (2008) have investigated the "ease with which patterns of mapping between signals and meanings can be learnt" (315). Crucial to learning signal-meaning mappings is regularity. Regularity is a form of compositionality. Compositionality is taken to mean that the meaning of a signal is a function of the meaning of its parts, and the way in which they're combined. Hypothesising that languages which contain regular and systematic signal-meaning mappings may be more easily learned and replicated, Tamariz and Smith conducted an artificial language learning experiment. Languages varied in levels of systematicity, from low

[2] See section 5.4.1.

to maximal[3]. Their 2008 experiment employed a similar procedure to the one used in the present dissertation – participants were exposed to meaning-signal pairs during training, and, during testing, asked to provide the signal (word) for an meaning presented alone, and also to select the corresponding meaning for words presented alone. Meanings consisted of coloured shapes, each with an internal shape, presented visually, whilst signals consisted of textual presentation of three-syllable words. Their results indicated that, although there was large variation between participants, they were, overall, sensitive to the level of regularity in place, and readily reproduced it. Indeed, in some cases, participants imposed regularity where it had not been present before. Thus, we see further evidence for a systematicity bias in humans. This study was performed using literate subjects and text-based stimulus, in an attempt to address the ease with which patterns of mappings between signal and meaning can be learnt.

Discussion

Both computer simulations and experiments with human participants have identified language to be a complex adaptive system, which adapts to constraints on learning in order to become easier to learn, through increased structure. This structure creates an example of "apparent design" seen in language, compositionality, where the meaning of a linguistic device (i.e. a sentence) can be inferred by the meaning of the sub-parts of the linguistic device, and the way in which they are combined. Furthermore, systematicity bias has been found in laboratory studies using human participants (Kirby Cornish & Smith 2008, Tamaríz & Smith 2008). The present dissertation will further investigate the mechanisms which aid recognition of regularity in language and development of systematicity bias, using two experiments.

[3] This was measured using *RegMap* (section 5.4.1)

3. Background to Study 1

Study one explores the putative role of literacy in language learning, crucially questioning whether literacy enables a systematicity bias in humans. In order to address this, illiterate musicians will be taught and tested on a musical language, and their results compared to the results of both non-musicians and literate musicians (from Brown 2008). It is hypothesised that illiterate musicians will pattern with non-musicians, thus reflecting the role of literacy in the development of a systematicity bias.

3.1 The role of Literacy

In Western societies, literacy is seen as a fundamental right, and it is expected that young adults will emerge, after years of schooling, with the skills intact to succeed in a literate world. However, at times the system can fail, and there remains a minority of adults and children who do not have adequate literacy skills, because they were never taught or because they dropped out of school at an early age, amongst other reasons (Morais et al 1979: 325). Illiteracy is often spoken and written about in terms of a "handicap", "incapacity", or "deprivation" (Barton: 1994: 13), and is largely associated with poverty, crime, discrimination and other social aspects. Illiterate people are often described as isolated, dysfunctional, and at a disadvantage. But aside from the social aspects of literacy and illiteracy, what are the effects on language? The role of literacy has been studied extensively in the fields of sociolinguistics, neuropsychology and language policy. It has been claimed, and is widely recognised, that "learning to read and write introduces into the system qualitatively new strategies for dealing with oral languages, that is, conscious phonological processing, visual formal lexical representation, and all the associations that these strategies allow" (Reis & Castro-Caldas 1997: 445).

3.1.1 Phonology

It has been argued that children do exhibit some awareness of phonology, prior to learning to read (Wimmer et al 1991). Early studies (Zhurova 1973, Liberman et al 1974) attempted to assess this putative awareness in children between the ages of four and seven, using phonological rule-learning, and word segmentation tasks. It is clear from studying the papers above that the most dramatic increase in children's performance occurred between the ages of five and six in both studies – prime years for the inception of reading instruction. However, some researchers were slow to attribute this increase in performance to reading instruction, stating that it could be as a result of general cognitive growth at this time (Shankweiler & Liberman 1976).

Alongside preschool children, illiterate adults are largely unable to perform tasks of phoneme deletion, which has led Morais et al (1979) to state that "the ability to deal explicitly with the phonetic units of speech is not acquired spontaneously" (Morais et al 1979: 330). It seems that training to read allows the cognitive capacity for awareness of phonology to manifest itself. Ehri (1985, 1998, Ehri & Wilce, 1979) supports this view, stating that learning to read facilitates phonological awareness, allowing literate people to manipulate phonemic representations at a metalinguistic level. More recent work has highlighted the inability of illiterates to deal with pseudo words, and to manipulate phonologically related words. In order to repeat and manipulate pseudo-words, we must have an underlying phonetic representation of their orthography. This is lacking in illiterates, and thus they perform at much lower levels than literates in tasks such as these (Reis & Castro-Caldas 1997).

The Fromkin, Rodman and Hyams' 2003 claim that "a speaker of English 'knows' that there are three sounds in the word cat…You can segment the one sound into parts because you know English" (Fromkin Rodman & Hyams 2003: 232) has been disputed by the finding that "adult non-literate native speakers of English are unable to do phoneme deletion" (Scholes & Willis 1991: 219). Phoneme deletion tasks require the participants to delete a "sound" from a given word, (e.g. "fly" - take away /l/). However, "even 3rd-graders – provided they are readers – can do [this] without difficulty" (1991: 219). Again we see evidence that literacy has an effect on phoneme deletion tasks. In light of the above evidence, it would appear that internal knowledge of the orthography of the word is needed to segment words into component letters.

Reis and Castro-Caldas explain the differing performance of illiterate and literate subjects as due to differing knowledge of the phoneme-grapheme relationship. Furthermore, they attribute the relative preservation of semantic information to an underlying implicit, semantic processing mechanism. Reis and Castro-Caldas claim that, whilst literate people can use both implicit semantic information and explicit phonological analysis to interpret words and meaning, illiterate individuals rely solely on semantic information. They conclude that "subsidiary or secondary systems [phonological analysis] are developed through formal learning" (Reis & Castro-Caldas 1997: 448 – 449). Thus, literacy brings about the ability to interpret and manipulate phonological information, which aids in reading, writing, and, furthermore, verbal cognitive skills. Castro-Caldas et al (1998) suggest that "absence of knowledge of orthography limits the ability of illiterate subjects to repeat words correctly" (1998: 1060). We may conclude that "the acquisition of the alphabetic representation of language enables the language knower to transfer this way of representation…to speech" (Scholes & Willis 1991: 220).

3.1.2. Morphology

According to Fromkin Rodman and Hyams (2003: 105), "the mental grammar of the language internalised by the language learner includes a lexicon listing all the morphemes, as well as the derived forms with unpredictable meanings". This may be taken to mean that humans have an internal ability to manipulate morphemes and derived word forms. However, illiterates perform very differently to literates on tasks of morpheme manipulation – performing like the literates just 23% of the time. Thus, illiterates are unable to perform morphemic analysis (Scholes & Willis 1991: 221). The authors provide further evidence that literate children could perform this task well, which supports the claim that literacy enables morphemic analysis.

Nunes et al (2006) state that understanding the morphology of words comes about via learning to spell – an aspect of becoming literate. They performed a longitudinal study on children who were learning to spell, and found that "learning to use morphemes in spelling does have an effect on children's representation and awareness of their own language" (Nunes et al 2006: 782). Furthermore, Nunes et al draw on evidence that shows that awareness of morphology influences and predicts later spelling ability (Nunes et al 2003), to conclude that the relationship between spelling and morphology is bi-directional.

3.1.3. Syntax

Literacy enables the analysis of syntactic rules which are "not part of the syntactic competence of non-literates" (Scholes & Willis 1991: 223). This is seen in high error rates shown by illiterates in tasks of syntactic comprehension. Scholes and Willis noted that illiterates employed sentence interpretation strategies which are found not only in non-literate adults but also in pre-literate children, congenitally hearing-impaired people, certain aphasias, and additionally in readers of English who do not use it for day-to-day interactions (See Scholes and Willis 1991: 223 for full references). This seems to provide further evidence for the effects of literacy – it would appear to enable precise syntactic analysis.

Discussion

It seems clear that literacy provides readers with metalinguistic knowledge which enables phonological, morphological and syntactic analysis. It appears that "phonemic or morphemic representations of lexical items, and the syntactic rules that describe the generation of sentences" are not held in the illiterate person's knowledge about their language (Scholes & Willis 1991: 224). As has been stated by Chall (1983: 2), "the influence of the development of reading and writing – 'literate intelligence' – on general cognitive development has unfortunately been underestimated". Thus, the role of literacy on language learning must be considered. Brown (2008) found that "musical literacy, like orthographic literacy, appears to create an awareness of subunits, which are the indicators of structure in a system" (Brown 2008: 57). Brown also suggested that systematicity biases found by Tamariz and Smith (2008), and Kirby, Cornish and Smith (2008), were as a result of participants using their orthographic literacy to analyse systematicity in language learning tasks. So, music was used as a substitute, in an attempt to isolate the possible effects of literacy on systematicity bias. This present study will isolate the effects of literacy versus practice and other kinds of knowledge on the development of sensitivity to systematicity in language.

3.2. Musical literacy

In order to seek further insights into language, this dissertation will test the possible effects of musical literacy and practice by extending the paradigm used by Brown (2008). Whilst Brown tested both musicians and non-musicians on a musical language learning task, this paper will test musicians who play and practice often, but who don't read music – so-called "illiterate" musicians. But how can we define literacy with regard to music?

Jerrold Levinson (1990) has defined musical literacy in two ways. The first concerns "factual information" which "a common reader is expected to possess and which enable[s] him or her to understand discourse which takes music or musicians as its subject" (Levinson 1990: 18). In supplying examples, Levinson puts forward information which most people in the Western world are aware of – that Beethoven was a composer of great merit. However, he then gives an example of more sophisticated knowledge, such as that the submediant is the name of a scale position, or that a major third is an interval. This first definition of literacy poses some problems – first, it is unclear what Levinson means when he refers to the "common reader". Additionally, the two examples he gives to illustrate his point contain very different information. The first is information which most lay-people are aware of, and the second concerns the more technical aspects of music such as intervals and scale positions, which comes only with training in musical theory. However, by this definition, our "illiterate" musicians would indeed be cast as illiterate, as although they are likely to be aware of Beethoven's skill as composer, they are highly unlikely to be versed in harmonic intervals and other theoretical aspects of music.

Levinson's second definition of musical literacy concerns literacy as "a component of broad cultural literacy" (Levinson 1990: 18). From this point, Levinson departs from the basics of literacy – knowledge of notation and form, to discuss literacy as a function of musical reception. This highlights the discrepancies found in definitions of musical literacy. Some focus on the interpretation on musical texts – Stewart et al (2003) considered experimental subjects to be musically literate when they could solve both implicit and explicit music reading tasks, and interpret musical text on a keyboard. However, Levinson defines musical literacy with regard to broader cultural literacy. For example, were we to follow, to the letter, Levinson's description of musical literacy – "it is responding to secondary features of musical structure – timbre, tempo, dynamics, phrasing, in a way framed by awareness of the physicality of the instruments which made that structure sound" (Levinson 1990: 25), then our "illiterate" musicians would be defined as literate, as they surely have an understanding of the physical form and function of musical instruments, and do respond to features of music such as timbre, tempo, etc. The discrepancy seen above between definitions of literacy highlights the need to make clear distinctions between musical literacy as a textual interpretation skill, and as a facet of cultural literacy. In this dissertation, we will deal solely with the former – musical literacy as the ability to read, write, and interpret musical notation, directions, and phrasing and dynamic markings etc.

It should be noted that Levinson's discussion of musical literacy makes no reference to the ability to write music. In natural language, it might be presumed that one who is literate reads and writes to a roughly equivalent extent. However, whilst many literate musicians may have the ability to write music (and this is not a guarantee), most do not do so on a day-to-day basis. It is only perhaps composers who write music to a similar extent to which orthographically literate participants write language. Thus, orthographic literacy reflects both an active (writing) and a passive (reading) form, whilst largely, musical literacy is restricted to the passive. This may be reflected in a differential processing of musical and linguistic data, and thus must be taken into account when interpreting the results of musical language learning experiments.

3.3. The role of Practice Strategies

Many studies (Nielsen 1997, 1999, Weinstein & Mayer 1986, Williamon & Valentine 2002) have attempted to isolate the role of practice strategies in the acquisition of musical competence. These studies have largely focused on literate musicians performing in the Western musical repertoire, and have shown that musicians are "methodical" in practice (Weinsten & Mayer 1986), and that they "break tasks down into component processes when practicing" (Nielsen 1999: 275). These include segmenting the piece into sections, playing in different tempi, changing the rhythmic structure, and, in some cases, bi- or uni- lateral playing - i.e. splitting the keyboard part into hands, and playing those separately (Nielsen 1999: 279). Williamon and Valentine (2002) also found that musicians segment a musical piece at structural bars, this practice increasing as ability increased. This finding was replicated by Chaffin and Imreh (1997). These strategies can be seen as "behaviours and thoughts that a learner engages in during learning and that are intended to influence the learner's encoding process" Weinstein & Mayer (1986: 315). The learning strategy may be designed to affect the learner's motivational or affective state, or the way in which the learner organises and integrates new knowledge. Thus, these strategies both indirectly and directly influence the acquisition of knowledge. Surely this systematic use of learning strategies furnishes musicians with a systematicity bias – an ability to "pick up" upon systematicity in music?

However, as stated above, these studies have focused on literate musicians. Thus, the results of these studies, and their implications upon practice in music, cannot be extended to "illiterate" musicians. So, the question remains, does practice alone enable "illiterate" musicians to be susceptible to systematicity in music? It could be argued that illiterate musicians make more use of practice strategies than their literate counterparts, due to their illiteracy. In other words, literate musicians can become aware of a large part of the structure in a musical piece, simply by reading it. This is unavailable to illiterate musicians, and thus, they must use practice strategies in order to become aware of structure. Thus, the possible role of systematic practice strategies cannot be overlooked in this investigation into the trigger for systematicity bias.

3.4. Musical language as a model of natural language

As Theodore Adorno has written: “music resembles a language” (1992: 1). Darwin himself, in his 1871 publication *The Descent of Man,* noted similarities between music and language, and used these as evidence for a proposed “protolanguage”. But what are these similarities between music and language? Fitch (2009) states: “The central shared aspects are prosodic and phonological: the use of a set of primitives (syllables) to produce larger, hierarchically structured units (phrases) which are discretely distinctive”. There is a tangible similarity between the tone-notation, and phoneme-grapheme, relationship, and music theory has often called upon linguistic terms such as sentence, phrase, subordinate phrase and others, to describe musical segments (Adorno 1992: 1). Erickson (2001: 11) has referred to “music-like features of speaking” – prosody, intonation, and paralanguage – which are commonly referred to as pitch, volume, and timing in speech. Lerdahl and Jackendoff (1983) used these similarities to attempt a generative theory of music, along the lines of generative linguistics. They state that these similarities or parallels support “a claim that these areas are a respect in which human musical and linguistic capacities overlap…both capacities make use of some of the same organising principles to impose structure on their respective outputs” (Lerdahl & Jackendoff 1983: 330). Indeed, as Schenker, father of Schenkerian analysis, wrote, “the secret of balance in music lies in the permanent awareness of levels of transformation and of the movement of the surface structure towards the initial generative structure, or of the reverse movement” (Schenker quoted in Deliège 1984: 59). The analogy between music and language can easily be made, on the strength of this quote alone. Furthermore, it has been suggested that musical training works upon a prior disposition to “internalise regularities of the auditory environment” (Bigand & Poulin-Charronnat 2006: 101), in order to create sophisticated musicians. This is analogous to our predisposition to language. It has also been suggested that “musical abilities develop naturally up to ten years, but do not evolve longer without explicit musical training” (Bigand & Poulin-Charronnat 2006: 101). This is analogous to the critical period hypothesis for language.

Furthermore, a meta-musical awareness has been proposed. Analogous to readers learning to distinguish and manipulate sounds in a language, Werner (1948: 54) suggested that listeners with musical training (literate musicians) perceive melodies as series of "single tonal motifs and tones which are distinct elements of the whole construction". Thus, while non-musically-trained people perceive the whole melody as one entity, musicians perceive the tones as separate entities, to be combined and recombined to form motifs and tunes. As a literate person cannot "shut off" their reading ability, neither can a musically literate individual "shut off" this process.

A musical syntax has been proposed, which reflects "the ability of listeners to expect chords according to their harmonic relatedness to a preceding harmonic context" (Maess et al 2001: 540). Maess et al state that this musical syntax "can only rely on a representation of the principles of harmonic relatedness described by music theory" (2001: 542-3). Furthermore, this musical syntax has been isolated in Broca's area and its right hemisphere homologue, the areas of the brain which process linguistic syntax. It has long been agreed that the left hemisphere of the brain (in the right-handed majority) serves specialised linguistic functions, which analyse the linguistic stimulus into its component parts. The right hemisphere is implicated with non-linguistic function, and holistic analysis of stimuli (Kellar & Bevar 1980: 24). Much work aimed at isolating musical function has used non-musically-experienced participants, and found that the recognition of melodies was superior in the left ear over the right (Spreen et al 1970). This would indicate right hemisphere lateralisation for music. However, Bever and Chiarello (1974) used both musically experienced and musically naïve participants in a study of cerebral dominance, and found that lateralisation depended on experience. Experienced listeners had a right-ear superiority, whilst naïve listeners had left-ear superiority. The naïve listeners treated the melodies as unanalysed wholes, and thus used their left ear (right hemisphere) to interpret it. However, the musically experienced listeners had a dominant right ear (left hemisphere) as they analysed the melody into its constituent parts. Thus, music training may have "real neurological concomitants, permitting the utilisation of a different strategy of musical apprehension that calls on left hemisphere functions (Bever & Chiarello 1974: 539).

Discussion

The studies mentioned above highlight the analogies between music and language. Thus, in order to isolate cultural aspects of language learning, musical languages may be a useful substitute for natural language. Whilst it is difficult to find both literate and illiterate people of comparable socioeconomic status and educational level, as "it is very easy to confound illiteracy with cultural aspects" (Reis & Castro-Caldas 1997: 444), the same does not hold for music. A smaller percentage of the population is musically literate than orthographically literate. Furthermore, in study one, educational aspects will be controlled by the use of university students as participants.

4. Background to study 2

Study two is concerned with meaning in language. Orthographically literate participants will be taught and tested on a spoken language. The results of this experiment will be compared to the results of Brown's 2008 musicians, who were taught and tested on a musical language. Music, unlike language, does not carry referential meaning. Thus, the results of this study will highlight the role of referential meaning in artificial language learning. It is hypothesised that referential meaning is irrelevant to artificial language learning, and that musically literate participants will match the performance of orthographically literate participants, thus validating the use of musical language as a model for natural language.

4.1. Language and music – Differences in meaning

Whilst music and language, as uniquely human skills, share many similarities – both have a hierarchical structure, both use expressive phrasing, and both share modes of expression (textual and vocal), they do differ on a few points. According to Fitch's 2005 account, adapted from Hockett's 1960 classification of design features of language, music does not feature arbitrariness, displacement, or duality of patterning (Fitch 2005: 32). Trehub, however, disputes the question of duality of patterning, whilst stating that "although both music and language show duality of patterning…the resulting musical pieces are not meaningful in the same way that verbal utterances are" (Trehub 2003: 669).

However, the most obvious distinction between music and language is with regard to meaning. Whilst music does carry emotional meaning, and indeed can evoke strong emotional reactions in listeners and performers alike, it does not carry the propositional meaning which language does. As Adorno (1992: 1) states, "It is customary to distinguish between language and music by asserting that concepts are foreign to music". Lerdahl and Jackendoff state this clearly: "Whatever music many 'mean' it is in no sense comparable to linguistic meaning: there are no musical phenomena comparable to sense and reference in language, or to such semantic judgements as synonymy, analyticity and entailment" (Lerdahl & Jackendoff 1983:

5). Music may be seen as having “floating intentionality” (Cross 2005: 30). As Cross puts it, “it can be thought of as gathering meaning from the contexts within which it happens and in turn contributing meaning to those contexts” (Cross 2005: 30). Adorno states: “music points to true language in the sense that content is apparent within it, but it does so at the cost of unambiguous meaning, which has migrated to the languages of intentionality” (Adorno 1992: 3). Thus music is ambiguous in meaning, and can mean many things to many people. As Fitch (2005: 31) states, “musical meaning is notoriously hard to pinpoint”.

This dissertation aims to address questions of meaning in musical and spoken languages. Musical stimulus, as seen above, doesn’t carry referential meaning, whilst spoken language does. Does this referentiality affect the learnability of the artificial languages? Additionally, the results of this study will address the validity of using music to model language.

5. Study 1 – Literacy

5.1. Experimental paradigm

The musical paradigm used in this dissertation is one developed by Brown (2008), with the "aim of mirroring as closely as possible the factors associated with orthography and language" (Brown 2008: 35). As seen above (section 3.4), the relationship between musical tone and notation closely resembles the phoneme - grapheme relationship in language. In order that participants may easily and reliably perceive and reproduce the musical language, Brown employed the Western music scale. Although this is but one musical scale of many – another example is the Indian Sargam, the equivalent of Solfege, the modal Raga, or the Javanese scale – it is doubtless familiar to most Western adults, particularly the experimental participants commonly used in university-based research – college students.

As can be seen in Figure 2 overleaf, the meanings to be signalled by the musical language differed on three dimensions (colour, shape, insert), and three variants of each dimension, (e.g. yellow, red, blue). Signal units made up of one musical interval (pair of tones) referred to each component of the meaning space. Each signal unit (interval) began with middle C (C4). This was chosen as the base note, in order that participants could reliably vocalise the interval. The second note, in the ascending scale, could be E4 (interval of 4 semitones), G4 (7 semitones), B4 (11 semitones, C4 (unison), or C5 (12 semitones, perfect octave). Moving down in pitch, the second note after the base C4 could be B3 (interval of 1 semitone), G3 (5 semitones), E3 (8 semitones, or C3 (12 semitones, perfect octave).

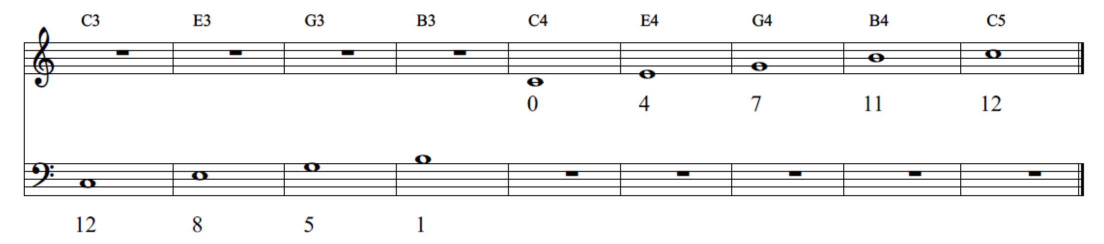


Figure 1. Intervals used to construct signal units in the musical language. Figures above the stave indicate note names, while the figures below the notes indicate the distance in semitones from C4, the base note for each interval[4].

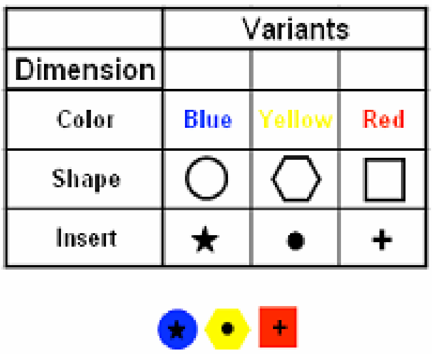


Figure 2. Meaning dimensions and variants. Below are sample composite meanings. Figure taken from Brown (2008: 41)

Brown (2008) developed three musical languages[5] using this system, each with differing levels of compositionality. One language (L1) was created by "randomly combining possible signal units into strings of three, which were then randomly assigned to meanings" (Brown 2008: 43). This created an entirely holistic language, with "no regular mapping between signals and meanings" (Brown 2008: 40). L1 had a compositionality level of 0.00458[6] for the full language, and 0.00395 for the language after the 50% bottleneck had been applied. This means that less than 5% compositionality was in place in L1, with this figure dropping to less than 4% after the application of the bottleneck. L3 was a fully compositional language, in which each interval corresponded to one individual component of meaning. In this language, colour was encoded by the first signal unit, shape by the second, and insert by the third. L3 had a compositionality level of 1 (full compositionality), with 0.42546 for the language after the 50% bottleneck had been applied. L2, the partially

[4] Software from www.musescore.org/en used to create figure 1.
[5] To be found in Appendix I
[6] Out of a possible value of 1. This was measured using *RegMap* (section 5.4.1)

compositional language, was designed in a similar fashion, but with "exceptions for each meaning component" (Brown 2008: 40). This was created by altering signal-meaning mappings from L3, to create a compositionality level of 0.66615, and 0.29390 after the bottleneck has been applied. The compositionality levels above refer to the segmentation of meaning and signal spaces. However, other methods of segmentation would produce different figures.

Brown imposed a 50% bottleneck during training – thus only half of the meaning-signal pairs were seen during training. However, during the testing phase, every meaning was shown to the participants, and a response required. Crucially, this bottleneck allowed Brown to investigate how participants reacted to differing systematicity levels, and observe how they created their own signals for novel meanings (Brown 2008: 40). Brown found that when producing output, musicians extended the compositionality levels encountered in the input. No non-musicians attained levels of compositionality anywhere near the musicians' output languages. Brown suggests this as evidence that musical literacy provided the musicians with a tool for analysing input, to discover systematic relationships (Brown 2008: 52). Brown tested separate groups of musicians and non-musicians on these languages. In order to allow reliable comparison to the group in question in this paper - "illiterate" musicians - the same musical languages will be used in this study.

5.2. Experimental setup

For this experiment, sound files created by Brown (2008) were used as stimuli. Adobe Audition was used to create pure tones 330 ms in duration. Tone pairs, which each constitute one signal unit, were created by inserting 150 ms of silence between a C4 and each of the designated nine tones (see figure 1). Tunes were then created by inserting 550 msecs of silence between each of three pairs. Each time a participant was presented with a meaning (picture), the word (tune) that corresponded with that meaning was played three times, with 6000 ms of silence between each repetition.

In all, seventeen illiterate musicians were recruited through the University of Edinburgh's careers website. Each participant was required to play and practice regularly, but to have had no instruction in musical notation. This is in contrast with both the musicians used by Brown (2008), who were musically literate, currently practicing, and had a mean practice time of 17.5 years, and the non-musicians, who had no musical background. Participants used in the present experiment were also required not to be colour-blind (as the stimulus images featured a colour variant), and not to speak a tone language. Recent research (Deutsch et al 2004, 2009) has shown that, whilst absolute pitch "the ability to name a musical note in the absence of a reference note" (Deutsch et al 2009: 2398) is rare in North America and Europe (less than one person in 10,000), speakers of a tone language were much more likely to have absolute pitch than non-tone language speakers. Deutsch et al claim that this enhanced prevalence is language-related rather than genetic (Deutsch et al 2009: 2402). However, Dediu and Ladd (2007) have pioneered investigation into possible genetic factors determining the existence of tone languages. Having examined the population frequency of both derived gene haplogroups ASPM and Microcephalin (relevant to brain growth and development), and the presence of tone languages, Dediu and Ladd conclude that this "relationship between genetic and linguistic diversity" may be causal (2007: 10944). This causal relation may be mediated by a "cognitive bias relevant to the processing and acquisition of tone" (2007: 10947). Despite discussion over genetic factors, tone-language speakers were excluded from the experiment, in order to control for possible effects of absolute pitch.

Due to equipment malfunction (two cases), tone deafness (two cases), and failure to complete the experiment (one case), five participants were excluded from analysis. Thus, twelve participants completed the experiment satisfactorily, four in each of the three levels of compositionality. Of this twelve, only one was female. It proved very difficult to recruit female illiterate musicians, which perhaps reflects a gender-based difference in social roles which is outside the scope of this paper. Participants ranged from 19 years and 6 months to 28 years and 6 months, with a mean of 22 years and 6 months.

5.3. Procedure

Both experiment 1 and experiment 2 were conducted in a sound deadened booth in an experimental lab. Participants were presented with visual stimuli on an Apple MacBook, and auditory stimuli via headphones attached to the MacBook. Vocal output from the participants was recorded on a Microtrak recorder connected to a head-mounted microphone. The experiment was designed using Psyscope, and adapted from the script used by Tamaríz and Smith (2008). Signals were replaced with sound files in the case of both experiments.

Experiments were run individually, and were anticipated to take between 25 and 40 minutes in total. The experimental procedure was identical in each of the two experiments. Participants were instructed that they would be trained and tested on an artificial language (either musical or spoken). They were told that they would see a meaning image on the screen, and would hear the sound paired with it (tune or spoken voice. This sound would be repeated three times, and participants were instructed to repeat the sound each time they heard it, in order to best learn the language.

The experimental procedure was conducted as follows:

1. Instructions
2. Training

    2.1 Round 1 - Image displayed and sound (tune or voice) played. Sound repeated three times with silence[7] between each repetition, for the participant to vocally repeat (x 14 images)
    2.2 Break
    2.3 Round 2 (As round 1)
    2.4 Break
    2.5 Round 3 (As round 1 & 2)

3. Break. Instructions for testing phase
4.Testing

    4.1 Image displayed and participant asked to "name" it (x 27 images)

5. End

[7] Musical experiment = 6000 ms, Spoken experiment = 4500ms (see section 6.2 for clarification).

Responses to both training and testing were recorded using the Microtrak recorder. The experimenter waited in an adjacent room to the participants, from where their performance could be monitored, without inhibiting their responses. After the experiment was complete, each participant was asked to fill out a questionnaire about their approach to the task, and an informal discussion of the task was conducted, in order to elicit further reactions from the participants about the task. Each participant was rewarded with £5 for their participation.

5.4. Analysis

The output intervals created by the illiterate musicians were calculated using the frequency analyser employed by the Adobe Audition 1.5 package. This analyser was set at 65,536 samples per second, and assigned the frequency of each note to the nearest semitone. The accuracy of the analyser was tested periodically, by comparing intervals played on a keyboard to the output created by participants. Consistent with Brown's (2008: 45) findings, occasionally the analyser assigned an obviously incorrect semitone to a note. On these occasions, the keyboard was used to correctly identify the original note.

5.4.1. *RegMap*

The data taken from the participants and from Brown's 2008 musicians and non-musicians was analysed for regularity between signals and mappings – i.e., how faithfully the participants reproduced the compositionality they heard in the input languages. Their output was compared to the input, using *RegMap,* a new measure of regularity of mapping between signals and meanings. Other methods of quantifying this relationship have been used by Kirby Cornish and Smith (2008: 10682), who calculated the correlation between differences in signals and differences in meaning (the Levenshtein edit distance calculates the smallest number of character insertions, deletions, or replacements needed to completely change one word into another), and Smith (2003) who correlated similarity in signals and similarity in meanings. However, *RegMap* is not based on similarity measures or correlations. It is independent of perceptual similarities in meaning and signal, and is bi-directional -

i.e., can be used to quantify the regularity of mappings from signals to meanings, and vice versa (Tamaríz & Smith 2008: 316). Tamaríz and Smith based their metric on redundancy – "the degree of predictability, order, or certainty in a system" (Tamaríz & Smith 2008: 317). This is, in essence, a measure of the degree of confidence that a signal element consistently predicts a meaning element (Cornish, Tamaríz & Kirby, In press).

The following equation gives the *RegMap* for a meaning element and a signal element.

$$\mathrm{Re}gMap = \sqrt{\left(1-\frac{H(S\mid M)}{\log(n_s)}\right)\times\left(1-\frac{H(M\mid S)}{\log(n_m)}\right)}$$

Here, *H(S | M)* is the conditional entropy of the signal segment given the meaning feature, or in other words the uncertainty about the meaning, given the segment. This relates to comprehension. *H(M | S)* is the conditional entropy of the meaning feature, given the signal segment, or in other words the uncertainty about the segment, given the meaning. This relates to production. The logs of *m* and *s* normalise these values between 0 and 1, with n_m being the number of different meaning values, whilst n_s is the number of different segment variants in the relevant segment position. Subtracting the conditional entropies *H(S | M)* and *H(M | S)* from 1 returns levels of confidence instead of uncertainty (Cornish, Tamaríz & Kirby, In press). Thus, *RegMap* tells us about comprehension and production, in measurements of degrees of confidence. All following analysis is based on these figures supplied by the *RegMap* program.

5.5. Hypotheses

It is hypothesised that literacy has a causal role in the development of metalinguistic representation, and systematicity bias. Whilst "practice" in a language is a necessary aspect for acquiring language, literacy may enable a systematicity bias, which allows literate people to pick up on compositionality in language, and reliably reproduce it. Thus, it is hypothesised that the illiterate musicians in this study will behave like the non-musicians seen in Brown's 2008 study.

5.6. Results

In order to provide comparison to Brown's 2008 findings, all participants were required to fill in a questionnaire regarding the experiment they had just performed. They were asked to rate the difficulty of the language-learning task on a scale from 1 (easy) to 5 (very difficult). Brown (2008: 46) found that her musician participants rated the task at 4.15, whilst non-musicians rated the task at 4.73. The illiterate musicians rated the task at an average of 4.29. Thus, the illiterate musicians seem to have rated the musical language-learning task like the musicians (4.29 as compared to 4.15). However, this is, of course, not the definitive measurement of this experiment.

Additionally, Brown found that her non-musicians took 28.2 minutes to complete the musical language-learning task, whilst the musicians took 28.5 minutes. The illiterate musicians studied here took marginally less time to complete the same musical language-learning task, on average taking 26.1 minutes. There was a difference in time taken by the illiterate musicians across compositionality levels - 30 minutes average for L1, 20.5 minutes average for L2, and 27.9 minutes average for L3. However, this can be explained by one participant having taken just 11 minutes to complete L2, causing the skew in average time seen here.

Interestingly, the majority of participants in L2 and L3, across experiments, answered in the questionnaire that they had recognised all of the pictures they saw during the testing phase. This is in contrast to the majority of participants in L1 who answered that they did not recognise all pictures. This indicates that the participants in L2 and L3 were unaware of the bottleneck in place. The response of the participants in L1 may be explained by a lack of confidence. Additionally, all but one participant across languages and experiments stated that they had tried to use some pattern or learning strategy to learn the meaning-signal mappings. This was seen even in L1, where no regular mapping existed. This indicates a strong familiarity with, and expectation of, regularity in each of the participants. This in turn suggests that systematicity bias is in place in these participants, and that they are applying this bias even to a totally random language. This supports the view of a systematicity bias. However, it does not address the possible causes of this bias. The present dissertation aims to cast light upon this.

5.6.1. Compositionality of output languages

We study the compositionality of the output languages created by each participant in order to address both how well the input was learnt, and also how the output languages were structured, in isolation from the input. Table 1 shows the compositionality levels for each group and language. The difference in average scores between groups (musicians, illiterate musicians, non-musicians) increased as compositionality of the input increased. It should be noted, however, that whilst both musicians and illiterate musicians increased incrementally in compositionality level as compositionality of the input increases, the non-musicians had a higher mean compositionality level in L2 than L3 (0.07951 to 0.01173). This indicates that perhaps the non-musicians were not picking up on the compositionality in the input languages, but rather, innovating their own structure.

A two-way independent ANOVA was performed on the data from each participant, and this highlighted a significant main effect of language ($p = 0.032$). Musical knowledge was shown to have a non-significant effect ($p = 0.135$), as was the interaction of musical knowledge and language ($p = 0.780$). Figure 3 clearly displays the significant effect of language – each group shows an increase in compositionality as input compositionality increases. However, figure 3 would also seem to belie the non-significant effect of musical knowledge, as non-musicians are markedly lower in compositionality, across all three languages.

	Musicians	Illiterate Musicians	Non-Musicians
Language 1	0.00360	0.00591	0.00477
	0.00351	0.00663	0.01700
	0.01700	0.00486	0.00507
	0.00940	0.00997	0.00228
	0.00618	**0.00684**	**0.00728**
	0.00794		
Language 2	0.04601	0.01146	0.02200
	0.04900	0.02773	0.26444
	0.01430	0.04649	0.00434
	0.00401	0.02939	0.02726
	0.10558	**0.02877**	**0.07951**
	0.00236		
	0.03688		
Language 3	0.07034	0.04218	0.01636
	0.01050	0.00816	0.01389
	0.11638	0.00252	0.00264
	0.08120	0.06376	0.01404
	0.02201	**0.02915**	**0.01173**
	0.04686		
	0.05788		

Table 1. Compositionality levels of each individual's output split into group and level. Numbers in bold are means.

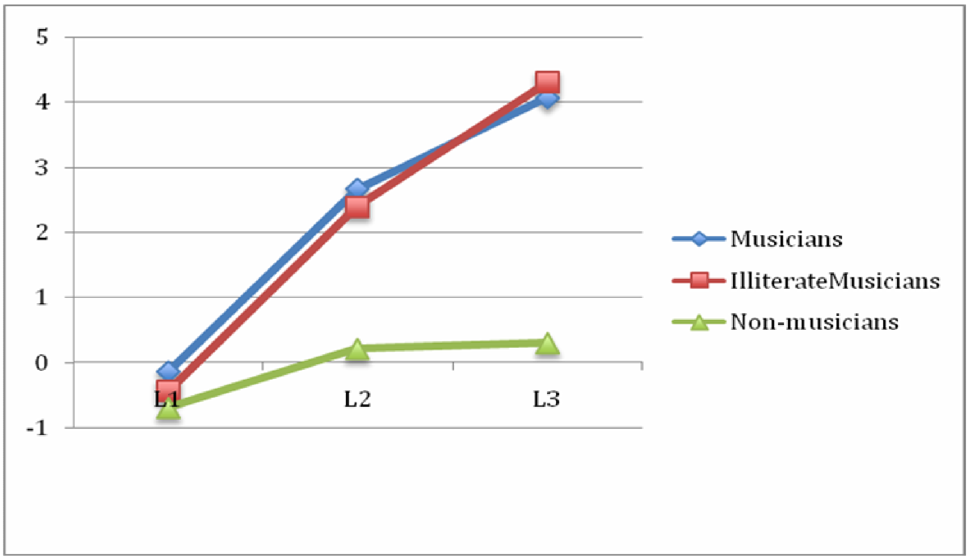


Figure 3. Compositionality levels of output languages[8]

5.6.2. Systematicity of output languages

The systematicity of each individual output language can be addressed by examining table 2, which presents the systematicity for each meaning-signal dimension, across group and language. *RegMap* figures for each signal-meaning dimension pair are reported here. This systematicity "determines how much a particular meaning is encoded in a particular signal unit" (Brown 2008: 49). On overall language scores (*RegMap* z-values), musicians had most highly significant values (6), with illiterate musicians having less highly significant values (4), whilst non-musicians had no highly significant scores overall.

[8] In figure 3 and all following figures, the Y-axis represents estimated marginal means (from statistical analysis).

Language	Musical Knowledge		Colour S1	Colour S2	Colour S3	Shape S1	Shape S2	Shape S3	Insert S1	Insert S2	Insert S3	RegMap (Language)
Language One	Musician	1	**3.208**	1.413	1.645	0.191	**1.071**	0.274	0.923	1.723	**0.722**	-0.798
		2	**1.252**	-0.298	1.809	-0.503	**-0.721**	-1.245	-0.190	-0.334	**-1.141**	-0.892
		3	**-0.081**	2.055	-0.610	-0.140	**-0.489**	-0.258	0.716	0.250	**0.702**	-0.172
		4	**-0.388**	0.890	-1.214	-0.231	**0.086**	-1.848	-1.550	1.884	**0.076**	1.340
		5	**0.537**	0.670	-0.027	-1.112	**-1.156**	-0.051	1.245	3.284	**-0.832**	-0.207
	Illiterate Musician	1	**-0.451**	-1.299	-0.351	0.058	**0.171**	0.540	1.877	0.514	**-0.569**	-0.549
		2	**0.651**	1.061	0.523	1.230	**-0.156**	-0.388	-1.152	0.296	**1.926**	-0.466
		3	**-0.316**	0.791	0.799	0.314	**0.089**	-1.236	-0.590	-0.139	**-0.941**	-0.756
		4	**0.237**	0.830	-1.481	0.009	**-1.072**	0.510	-1.248	-0.843	**0.427**	-0.014
	Non-Musician	1	**0.807**	-1.597	-0.089	-1.529	**0.481**	0.283	-0.001	1.222	**0.258**	-0.441
		2	**1.016**	1.512	0.479	-0.152	**-0.805**	-0.475	1.027	0.910	**1.085**	-0.864
		3	**0.894**	2.764	1.113	-1.128	**-0.636**	0.401	-0.833	0.228	**-1.671**	-0.654
		4	**0.509**	-0.540	1.813	0.656	**0.013**	0.934	-0.928	0.880	**1.904**	-0.834
Language Two	Musician	1	**-0.249**	0.273	-0.659	-0.343	**-1.978**	-1.715	0.035	3.973	**0.031**	1.457
		2	**6.691**	0.256	-0.684	-0.741	**0.169**	2.690	-1.205	-1.385	**-0.714**	4.969
		3	**-0.047**	-0.570	-0.584	-0.870	**-0.057**	0.059	-1.232	-0.141	**-0.594**	-0.458
		4	**2.093**	0.180	0.190	1.566	**0.132**	1.180	-0.801	0.024	**0.360**	-1.043
		5	**8.105**	1.162	-1.928	-1.142	**7.122**	-0.243	-1.182	-1.271	**7.429**	12.304
		6	**1.137**	-0.914	0.078	-0.071	**-0.226**	-0.179	0.499	-1.229	**-1.122**	-1.257
	Illiterate Musician	1	**1.321**	0.715	-0.048	0.862	**-0.860**	-1.187	1.239	3.221	**5.018**	-0.292
		2	**0.048**	0.875	-0.306	1.683	**0.880**	-0.361	1.289	-1.502	**6.629**	5.385
		3	**2.778**	-0.191	0.422	-0.744	**-0.364**	-0.627	-0.553	0.663	**0.109**	-0.049
		4	**-0.797**	0.842	5.169	-1.235	**1.450**	-1.777	-0.692	-1.213	**-1.835**	4.537
	Non-Musician	1	**0.665**	-1.299	-1.232	-0.188	**0.457**	-0.925	0.346	-0.046	**1.702**	0.401
		2	**2.899**	0.435	3.888	0.732	**-0.685**	1.464	0.501	0.095	**-0.287**	0.749
		3	**-0.804**	0.925	1.657	-1.250	**-0.911**	-0.192	-0.716	-1.151	**-0.341**	-1.479
		4	**0.078**	-1.165	0.613	0.533	**-0.114**	0.480	0.996	-0.650	**1.508**	1.151
Language Three	Musician	1	**4.036**	0.549	-0.720	-0.705	**4.699**	-1.752	-0.782	-0.397	**6.978**	7.996
		2	**3.581**	-1.375	1.292	-1.779	**0.884**	2.294	0.363	1.904	**0.084**	2.059
		3	**6.490**	0.625	-0.225	-1.096	**3.661**	-1.046	-1.515	-0.730	**8.037**	7.005
		4	**4.908**	-0.577	-0.854	5.210	**-0.500**	-0.136	0.283	4.771	**-1.423**	1.192
		5	**0.578**	0.527	1.200	2.905	**5.171**	-0.574	0.589	-0.846	**2.638**	1.454
		6	**0.109**	-0.094	-1.482	-0.565	**-1.561**	1.689	-0.370	0.496	**4.950**	4.673
	Illiterate Musician	1	**2.085**	-0.459	-1.639	-1.036	**4.043**	-0.779	-0.450	-1.396	**4.188**	6.862
		2	**-0.205**	-1.536	0.245	-0.147	**0.281**	-0.115	-0.340	3.757	**2.268**	1.103
		3	**-0.696**	-0.712	-0.724	0.672	**2.900**	0.507	-1.538	-0.554	**-1.184**	-1.631
		4	**7.179**	-0.120	1.077	-0.838	**5.491**	-0.647	-2.163	-1.531	**5.593**	10.886
	Non-Musician	1	**1.409**	0.183	1.288	4.021	**1.085**	0.050	-0.744	1.470	**-0.377**	0.237
		2	**-0.567**	-0.545	1.904	3.421	**1.124**	-0.326	-0.277	0.817	**0.067**	0.760
		3	**0.468**	0.484	0.936	-0.070	**-0.519**	-1.187	0.722	1.637	**-1.021**	-0.663
		4	**0.910**	1.619	-0.846	0.186	**0.163**	-0.883	1.516	0.830	**2.641**	0.275

Table 2. Systematicities for each meaning-signal pair, for each participant, in z-values. Numbers highlighted in blue indicate significance below 0.05, whilst those highlighted in yellow indicate significance below 0.01. Columns highlighted in bold are those in which meaning-signal mapping was systematic (languages two and three).

Discussion

As Brown (2008) found, in languages 2 and 3, some musicians produced quite regular languages. We can follow Brown's inference that these musicians have indeed learned the system in place in the input languages, as "their regular patterns extend to novel items only encountered in testing" (Brown 2008: 51). Whilst there is quite a variety in compositionality levels within languages, and overall the levels seems quite low, we can again follow Brown in suggesting that this could be as a result of the difficulty of the task faced by participants – regardless of the musical skill of a participant, vocally reproducing a segment which one has in mind is remarkably difficult. However, our results reflect Brown's findings that musician number 5 in L2 reflected the systematicity in the input, by mapping signal to meaning in a highly systematic way, according to the structure in place. Furthermore, musicians numbers 1 and 3 in L3 also behaved in the same manner. Additionally, these musicians exhibited high compositionality levels. Thus, we may conclude that these participants have learned the language.

Two illiterate musicians – numbers 1 and 4 in Language 3 - mirrored the input by mapping signal to meaning correctly. We can interpret this to mean that these illiterate musicians also learnt the language, as they extended learned patterns to novel items. The compositionality levels of the illiterates follow the patterns of the musicians, closely shadowing their compositionality (L1 IM mean 0.00684 to M mean 0.00794, L2 IM mean 0.02877 to M mean 0.03688). However, it is true that L3 does not reflect this tendency (IM mean 0.02915 to M mean 0.05788). Thus, while 2 participants in L3 did appear to learn the language and had high compositionality levels, the two other participants (numbers 2 and 3) lowered the average compositionality levels with their low performance.

No non-musicians learned the system in place to any degree – non-musicians had few significant systematicities. Although non-musicians actually had a higher overall compositionality level than both musicians and illiterate musicians in L2, this average level was in fact driven by one participant, who had a compositionality level of 0.26444 (table 1).

In summary, the evidence from the compositionality and systematicity levels shows that some musicians and illiterate musicians were able to learn and reproduce the compositional systems they were exposed to in the input. No non-musician learned the system, and non-musicians seem to have processed the input differently from the other two groups. A further look at each participant's data highlights the need to examine in detail each value, before accepting an overall mean figure.

5.6.3. Similarity of form

Examining the similarity of form, a measurement of whether, and how well, participants learned the form of the input language, allows us to examine how each participant, and crucially, each group, attempted to learn the language they were exposed to. Additionally, as a 50% bottleneck was imposed on the training phase, we can examine whether participants could both correctly reproduce "seen" items (items they were directly exposed to in the training phase), and generalise "unseen" items (items first encountered during testing). If participants consistently generalised the form and applied it to unseen items, we may conclude that they correctly analysed the system in place – i.e., learned the language.

Similarity of form was analysed in the same manner as Brown 2008. The output language for each participant was compared to the input language, and identical signal units noted. A distinction was made between signal units the participants had been directly exposed to in training ("seen" items), and signal units they first encountered in the testing phase ("unseen" items). Musicians averaged 9.92 seen, and 8.33 unseen, identical items in input and output. Illiterate musician averaged 6.17 seen and 5.17 unseen items, whilst non-musicians averaged 3 seen and 1.25 unseen items. Figures 4 and 5 show the estimated marginal means of seen and unseen items for group and language.

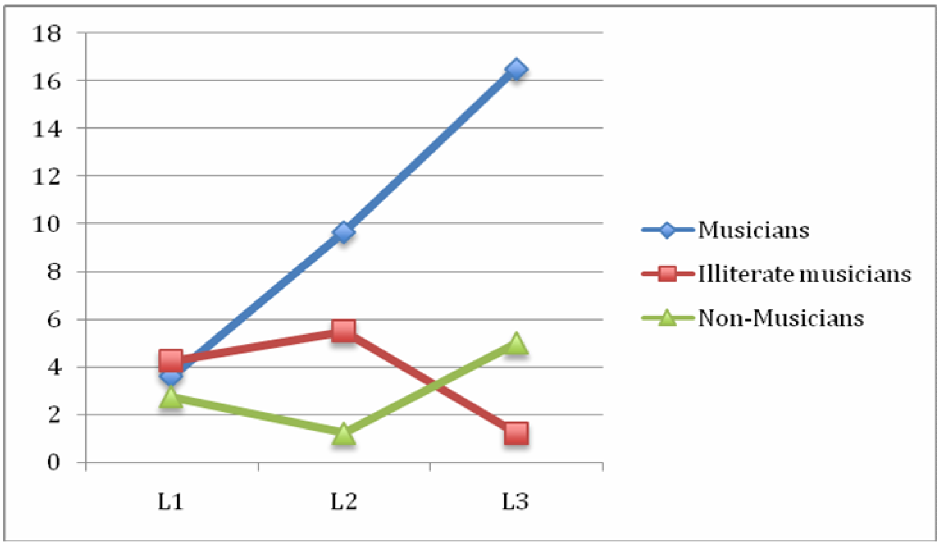


Figure 4. Number of signal units precisely reproduced ("seen")

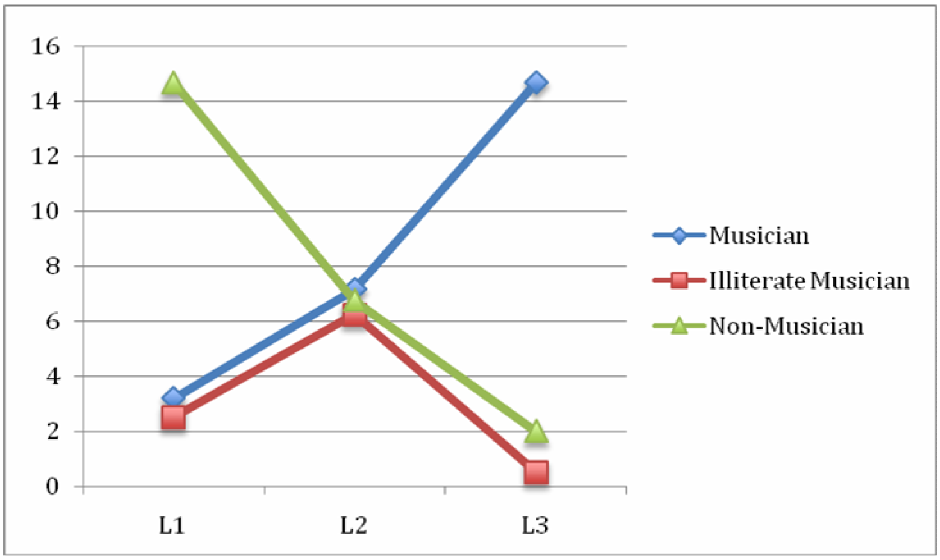


Figure 5. Number of signal units correctly generalized ("unseen")

A two-way independent MANOVA showed a significant main effect of musical knowledge for both seen ($p = 0.020$) and unseen ($p = 0.012$) items. There was also a significant effect of language for seen items ($p = 0.031$), and nearing significance for unseen items ($p = 0.069$). There was a non-significant interaction effect of language and musical knowledge (seen: $p = 0.410$, unseen: $p = 0.335$). However, figures 4 and 5 suggest, through crossing lines, an interaction effect for both seen and unseen items.

Discussion:

Seen items: Musicians correctly reproduced more seen items than non-musicians, across all three languages. Additionally, musicians correctly reproduced more seen items than illiterate musicians in L2 and L3. In fact, all 3 groups behaved almost identically in L1, whilst the musicians' performance was greatly increased in L2 and L3. Illiterate musicians performed well in L2, yet L3 was not learned to the same degree. Non-musicians trained on L2 performed worse than those trained on L1, however, those trained on L3 did increase in performance.

Unseen items: Again, both musicians and illiterate musicians performed almost identically on language 1, before the musicians' performance increased dramatically in L2 and L3. It is with non-musicians that we address learning strategies. Whilst non-musicians performed very highly on L1, their performance dropped dramatically on L2 and L3. Figures 4 and 5 clearly show the significance of musical knowledge, with each group behaving very differently – figure 5 shows the significance of language, while both imply an interaction effect. The small sample sizes may account for non-significant statistical results for interaction effects.

This data suggests that musicians both reproduced seen and generalised unseen items in a language once they had discovered an underlying structure (as seen by the marked increase in performance between languages 1, 2 and 3). Thus, musicians can be described as having learned the language. Illiterate musicians showed remarkably consistent internal behaviour in their approach to both seen and unseen items. The participants who were trained on L2 appear to have picked up on the system in place, whilst those who were trained in L3 were unable to do so. This suggests that the illiterate musicians did not accurately learn and reproduce the systems in place, rather that they may have simply memorised the input in L2, rather than noticing the systematic mapping of signal to meaning. Non-musicians were better able to reproduce seen items than generalise unseen items, indicating that they did not discover the underlying structure in place in the languages. Their overall performance was weak, indicating that non-musicians were unable to learn the language, but rather, appear to have memorised the input.

5.6.4. Structure of output compared to input

We study the structure of both output and input together, in order to address how input influences the level of structure in an individual learner's output. In order to address this, a weighted ratio of each participant's compositionality for output compared to input was calculated, using the equation:

$$(\text{output}/\text{input}) \times (\text{input} + \text{output}) = \text{weighted ratio}$$

In other words, the compositionality of each participant's output was divided by the compositionality of the input language they were exposed to, and in turn this figure was multiplied by the sum of the compositionality of output and input in order to give us a weighted ratio of output to input, for each participant.

In all languages, musicians scored on average higher than both musicians and illiterate musicians. In L1, musicians scored on average 0.018, whilst illiterate musicians and non-musicians scored 0.012 and 0.008 respectively. This pattern was reflected in L2 – musicians 0.048, illiterate musicians 0.033, non-musicians 0.022, and L3 – musicians 0.081, illiterate musicians 0.037, non-musicians 0.011. Figure 6 shows these weighted ratios in graphic form. Overall, illiterate musicians behaved unlike both musicians and non-musicians, instead occupying a space between both.

A two-way independent ANOVA showed a significant main effect of musical knowledge ($p = 0.042$). There was a non-significant effect of language ($p = 0.107$). However, as can be clearly seen in figure 6, language does appear to have an effect on ratio scores. There was also a non-significant interaction effect of language and musical knowledge ($p = 0.475$).

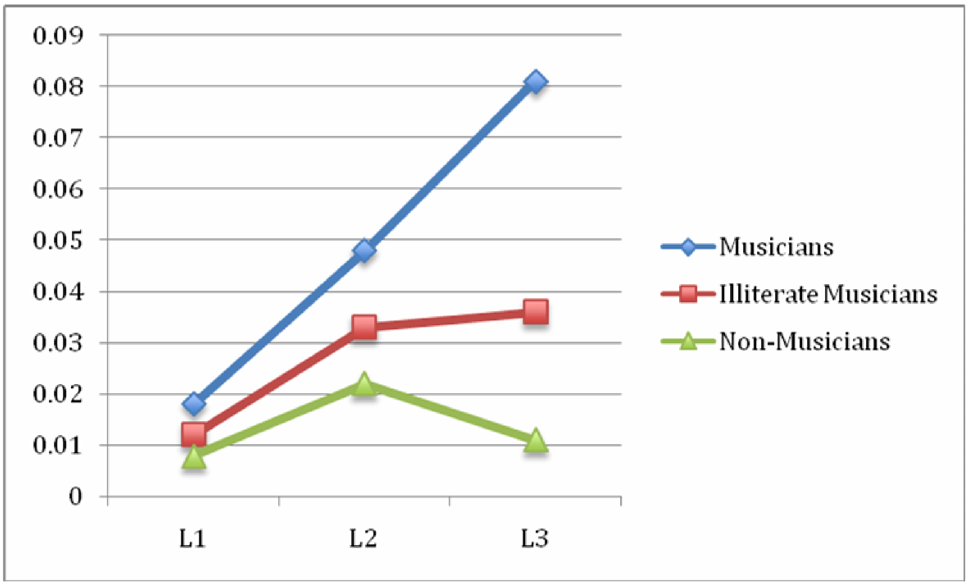


Figure 6. Weighted ratio for output compared to input

Discussion

Musicians appear more sensitive to structure of input than both illiterate musicians and non-musicians, scoring an almost equal ratio of output to input in L3 in particular. Non-musicians did not appear sensitive to the structure, increasing only slightly in ratio in L2, before decreasing in L3. Illiterate musicians did not behave like either group in this analysis, instead increasing slightly in performance as language compositionality increased. From this evidence we can conclude that musicians were most sensitive to the structure in the input. Illiterate musicians also showed some sensitivity, this is shown by their increase in mean weighted ratio between L1, L2 and L3. However, their highest ratio was still quite low. Thus, both musicians and illiterate musicians appear to have learned the language, although musicians were more successful overall.

6. Study 2 – Modality

6.1. Experimental paradigm

The spoken languages used in this experiment aim to resemble the musical languages used by Brown (2008). In doing so, each interval-based language used by Brown was translated into a syllable-based spoken language. Each of the syllables tu, ki, pe, lo, be, mu, ga, di, and na (from Tamaríz and Smith 2008) were arbitrarily assigned to one of the nine intervals found in the musical languages. Then, the languages were reconstructed, replacing syllables for intervals, to create pseudo-word strings of three CV syllables each. The spoken languages retained the compositionality levels of the musical ones. The resulting languages were tested for phonological neighbours, and none were found[9]. Literature on speech processing defines a phonological neighbour as "a word that can be created from the target by the addition, deletion, or substitution of a single phoneme" (Goswani 2006: 467). A word has a dense phonological neighbourhood when it has many phonological neighbours. Studies have found possible effects of phonological neighbourhood density. Demke et al (2002) found that, when children were exposed to phonological neighbours prior to learning a new word, their word production was not affected. However, when they were exposed to phonological neighbours after learning a new word, they correctly produced the target word more often than children who did not receive this exposure. Demke et al suggest that "exposing children to similar sounding words after a novel word has been introduced may have helped maintain a representation of the word in working memory, leading to enhanced word learning" (Demke et al 2002: 379). This implies that phonological neighbours are easier to learn. Thus, phonological neighbours were ruled out on the basis of this evidence, in order to reflect the difficulty of the musical language-learning task.

[9] www.essex.ac.uk/psychology/cpwd/searches/neighbourP_search.htm, accessed 14/05/09, 14:30

6.2. Experimental setup

Experiment 2 used vocal sound files as stimuli. These were recorded in the PPLS recording studio in the University of Edinburgh. Individual pseudo-word files were created, and trimmed using Adobe Audition 1.5. 200 ms of silence was inserted before and after each pseudo-word, to keep the signals internally consistent. The experimental paradigm was similar to the musical experiment, with minor differences. Following feedback from pilot trials, it was decided to reduce the time between each repetition of the word from 6000ms to 4500 ms. This was to reduce the chance that the participant would get bored during the experiment. This again highlights a difference in learning procedures between musical and spoken languages – the musical language participants needed the full 6000 msecs to internalise the training word, whilst spoken languages participants did not.

Participants for the spoken language experiment were orthographically literate students of the University of Edinburgh, recruited via the University's careers website. Eighteen participants in all were recruited, and as above (section 5.2), participants were required to be non-tone language speakers, and not colour-blind. Due to equipment malfunction (one case), and failure to complete the experiment (three cases), four participants had to be excluded from the analysis. This left fourteen participants who satisfactorily completed the experiment, seven male and seven female. Four participants were taught and tested on language 1, five on language 2, and five on language 3. Participants ranged in age from 19 years and 11 months to 35 years and 7 months, with a mean of 23 years and 10 months.

6.3. Procedure

The procedure for both experiments 1 and 2 can be found in section 5.3.

6.4. Analysis

The output languages created by participants were manually transcribed and each output signal segmented into three syllables (eg. lo.mu.na). This gives us signal segments – i.e. word beginning, middle or end. This allowed us to use *RegMap* as a system of analysis, as *RegMap* provides us with a degree of confidence that a signal element consistently predicts a meaning element (Cornish, Tamaríz & Kirby In press: 7).

6.4.1. RegMap

The data from both the musical and orthographical participants was analysed using *RegMap*, which is described in section 5.4.1 above.

6.5. Hypotheses

This dissertation has attempted to highlight the similarities between music and language, in order to justify the use of a musical artificial language as a model for natural language. However, this can fall under criticism, as music does not carry referential meaning. Thus, whilst referential meaning is crucial for natural language learning, it is hypothesised that referential meaning is irrelevant for learning an artificial language. Thus, we might hypothesise that, in this study, our musically literate participants will learn and reproduce the compositionality in a musical language to a similar degree that the orthographically literate participants learn and reproduce the compositionality in a spoken language. This finding would validate the use of musical language as a model for natural language, in artificial language learning experiments.

6.6. Results

As seen above, participants were asked to fill in a questionnaire regarding the experiment. With regards to difficulty of the task, Brown's 2008 musically literate participants rated the language-learning task at 4.15, whilst the orthographically literate participants seen in this paper rated the task at a level of 3.71. There was not much variation in the ratings of the individual levels in the musical language, however L1 of the spoken language was rated at 4.25, whilst L2 and L3 were rated 3.8 and 3.2 respectively. This indicates that the orthographically literate participants found their task easier as a whole than the illiterate musicians found theirs.

Additionally, whilst the musicians took 28.5 minutes to complete the task, the orthographically literate participants took an average of just 19.4 minutes to complete the spoken language learning experiment. There was a noticeable difference in time taken between languages in the spoken experiment – L1 took an average of 22.25 minutes to complete, L2 took an average of 20.5, and L3 took an average 15.9 minutes. However, as orthographical participants were given less time in the training rounds, it is inappropriate to directly compare the time taken to complete the musical and spoken language learning tasks.

Again, as seen in section 5.6, the majority of participants in L2 and L3 answered that they had recognised all of the pictures they saw during the testing phase, whilst the majority of participants in L1 stated that they had not. We may draw the same conclusions here as we drew above in section 5.6, namely that the participants in L2 and 3 were unaware of the bottleneck. Furthermore, all participants tried to use some pattern to learn the language they were being exposed to.

6.6.1. Compositionality of output languages

Table 3 highlights the vast differences in compositionality seen in output languages between the musical and orthographic languages. Overall, the orthographically literate participants showed higher compositionality in the orthographical language (overall mean = 0.23851) than did musically literate participants (overall mean = 0.03423) in the musical language. Additionally, the compositionality levels increased with input compositionality, across both groups. This indicates that both groups were successfully learning the compositionality in each language.

	Musical Language	**Orthographic Language**
Language 1	0.00360	0.02167
	0.00351	0.00579
	0.01700	0.01535
	0.00940	0.01666
	0.00618	**0.01487**
	0.00794	
Language 2	0.04601	0.32448
	0.04900	0.01680
	0.01430	0.24607
	0.00401	0.10826
	0.10558	0.30920
	0.00236	**0.20096**
	0.03688	
Language 3	0.07034	0.77845
	0.01050	0.49694
	0.11638	0.24392
	0.08120	0.40524
	0.02201	0.57390
	0.04686	**0.49969**
	0.05788	

Table 3. Compositionality levels of each individual's output split into group and level. Numbers in bold are means.

A two-way independent ANOVA of this data showed a significant main effect of language ($p = 0.002$). A non-significant effect of modality was shown ($p = 0.121$). The ANOVA also highlighted a non-significant interaction effect of language and modality ($p = 0.391$). A closer look at figure 7 shows the significant main effect of language clearly. However, it also shows that orthographical participants scored, on average, more highly than musical participants. This suggests an effect of modality not addressed by the ANOVA.

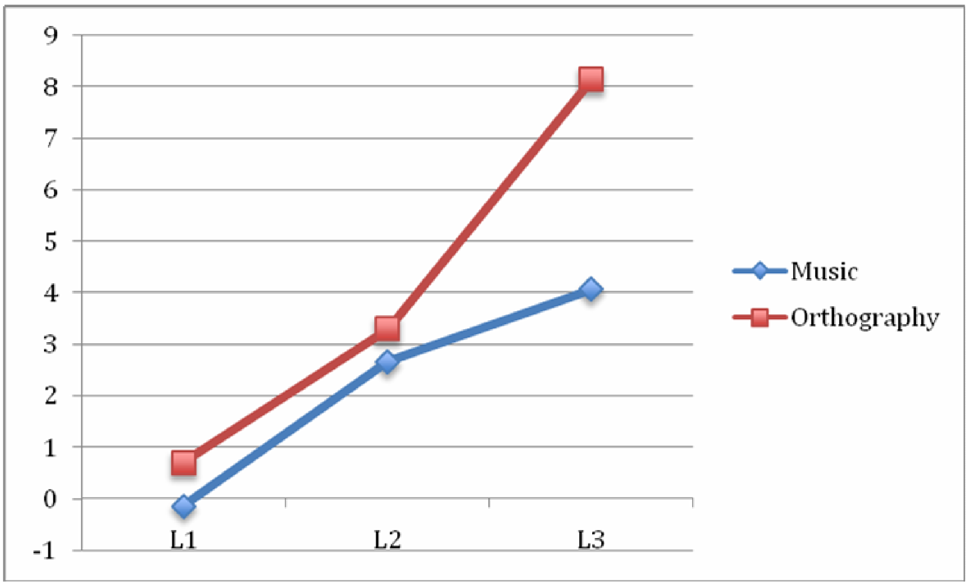


Figure 7. Compositionality levels of output languages

6.6.2. Systematicity of output languages

Table 4 below presents the systematicity for each meaning-signal dimension, across language and modality. Overall RegMap values clearly highlight the difference between modalities – orthographical participants scored higher than musical participants, scoring 9 highly significant values to the musician's 5 highly significant values.

Language one

		Colour S1	Colour S2	Colour S3	Shape S1	Shape S2	Shape S3	Insert S1	Insert S2	Insert S3	RegMap (Language)
Music	**1**	**3.208**	1.413	1.645	0.191	**1.071**	0.274	0.923	1.723	**0.722**	-0.798
	2	**1.252**	-0.298	1.809	-0.503	**-0.721**	-1.245	-0.190	-0.334	**-1.141**	-0.892
	3	**-0.081**	2.055	-0.610	-0.140	**-0.489**	-0.258	0.716	0.250	**0.702**	-0.172
	4	**-0.388**	0.890	-1.214	-0.231	**0.086**	-1.848	-1.550	1.884	**0.076**	1.340
	5	**0.537**	0.670	-0.027	-1.112	**-1.156**	-0.051	1.245	3.284	**-0.832**	-0.207
Orthography	**1**	**-0.289**	1.168	-1.028	-1.738	**-0.189**	1.233	2.238	-0.582	**0.189**	1.118
	2	**1.973**	2.748	1.466	0.478	**-0.060**	-0.393	0.593	0.266	**-0.583**	-1.227
	3	**1.927**	2.324	0.541	-0.808	**-0.935**	-0.593	3.326	0.124	**0.121**	0.797
	4	**-0.816**	-0.569	-1.296	4.046	**1.834**	-0.227	-1.273	0.696	**2.967**	2.124

Language two

		Colour S1	Colour S2	Colour S3	Shape S1	Shape S2	Shape S3	Insert S1	Insert S2	Insert S3	RegMap (Language)
Music	1	**-0.249**	0.273	-0.659	-0.343	**-1.978**	-1.715	0.035	3.973	**0.031**	1.457
	2	**6.691**	0.256	-0.684	-0.741	**0.169**	2.69	-1.205	-1.385	**-0.714**	4.969
	3	**-0.047**	-0.57	-0.584	-0.87	**-0.057**	0.059	-1.232	-0.141	**-0.594**	-0.458
	4	**2.093**	0.18	0.19	1.566	**0.132**	1.18	-0.801	0.024	**0.36**	-1.043
	5	**8.105**	1.162	-1.928	-1.142	**7.122**	-0.243	-1.182	-1.271	**7.429**	12.304
	6	**1.137**	-0.914	0.078	-0.071	**-0.226**	-0.179	0.499	-1.229	**-1.122**	-1.257
Orthography	1	**7.324**	-1.074	-0.709	-2.292	**-1**	-1.382	-1.765	1.115	**2.385**	9.461
	2	**-0.975**	1.789	-0.441	1.094	**0.553**	-0.745	0.558	1.243	**0.285**	0.876
	3	**10.088**	0.635	1.053	-1.268	**6.349**	-1.3	-1.056	-0.832	**3.907**	3.294
	4	**9.015**	-0.753	-2.223	-0.422	**8.135**	0.369	-1.536	-0.764	**8.887**	9.636
	5	**10.363**	5.919	1.961	0	**-0.178**	0.772	0	-0.294	**3.881**	2.23
	6	**7.324**	-1.074	-0.709	-2.292	**-1**	-1.382	-1.765	1.115	**2.385**	9.461

Language Three

		Colour S1	Colour S2	Colour S3	Shape S1	Shape S2	Shape S3	Insert S1	Insert S2	Insert S3	RegMap (Language)
Music	1	**4.036**	0.549	-0.720	-0.705	**4.699**	-1.752	-0.782	-0.397	**6.978**	7.996
	2	**3.581**	-1.375	1.292	-1.779	**0.884**	2.294	0.363	1.904	**0.084**	2.059
	3	**6.490**	0.625	-0.225	-1.096	**3.661**	-1.046	-1.515	-0.730	**8.037**	7.005
	4	**4.908**	-0.577	-0.854	5.210	**-0.500**	-0.136	0.283	4.771	**-1.423**	1.192
	5	**0.578**	0.527	1.200	2.905	**5.171**	-0.574	0.589	-0.846	**2.638**	1.454
	6	**0.109**	-0.094	-1.482	-0.565	**-1.561**	1.689	-0.370	0.496	**4.950**	4.673
Orthography	1	**10.539**	-1.163	-0.506	0	**8.735**	-0.407	0	-0.780	**8.358**	6.665
	2	**9.176**	0.813	-1.201	-1.271	**6.181**	-1.118	-1.314	-1.709	**9.664**	7.150
	3	**8.140**	-1.248	-1.970	0.500	**9.024**	-0.722	-1.538	-1.267	**9.041**	9.496
	4	**10.308**	-1.190	-1.243	0	**9.637**	-1.150	0	-1.177	**10.330**	7.740
	5	**8.985**	2.379	-1.277	-1.647	**-0.530**	-1.368	0.423	0.084	**10.196**	9.672

Table 4. Systematicities for each meaning-signal pair, for each participant, in z-values. Numbers highlighted in blue indicate significance below 0.05, whilst those highlighted in yellow indicate significance below 0.01. Columns highlighted in bold are those in which meaning-signal mapping was systematic (languages two and three).

Discussion

The ANOVA performed on this data concluded a non-significant effect of modality. However, a closer look at the data is warranted here. As can be seen from table 4, in L2, 3 orthographically literate participants, (numbers 3, 4 and 5) mapped from signal to meaning highly systematically, reflecting the system in place in the input. This is in contrast to just one musician in language 2 (number 5) who behaved in the same way. In L3, four out of five orthographical participants (numbers 1, 2, 3, and 4) reflected the input systematicity, compared to just two musicians out of six (numbers 1 and 3) who successfully achieved this. Thus, 80% of orthographical participants learned L3, whilst just 33.33% of musical participants did. From this, and the high compositionality levels achieved by the orthographical participants, we can conclude that they successfully learned and reproduced the language, and, crucially, that they did so with much more success than the musically literate participants learned their languages. Thus, it would appear from the evidence to hand thus far that an orthographical language is more easily and readily learnt by an orthographically literate individual than a musical language is learnt by a musically literate individual. As the spoken language was designed to reflect the difficulty of the musical language, it seems clear that orthographical (i.e. referential meaning-based) language is more easily learnt than a musical (i.e. non-referential) language. Thus, reference seems crucial to successful artificial language learning.

6.6.3. Similarity of form

As we have seen above, musical participants averaged 9.92 seen items and 8.34 unseen identical items in input and output. Using the same measurement of similarity of form as seen in section 5.6.3, orthographical participants were found to have averaged 21.23 seen and 14.75 unseen items. Figures 8 and 9 show averages for group and level for both seen and unseen items.

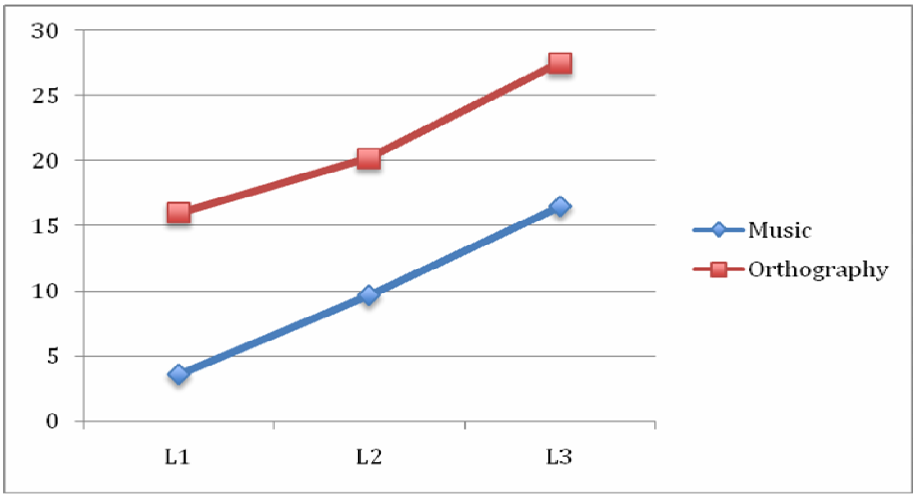


Figure 8. Number of signal units correctly reproduced ("seen")

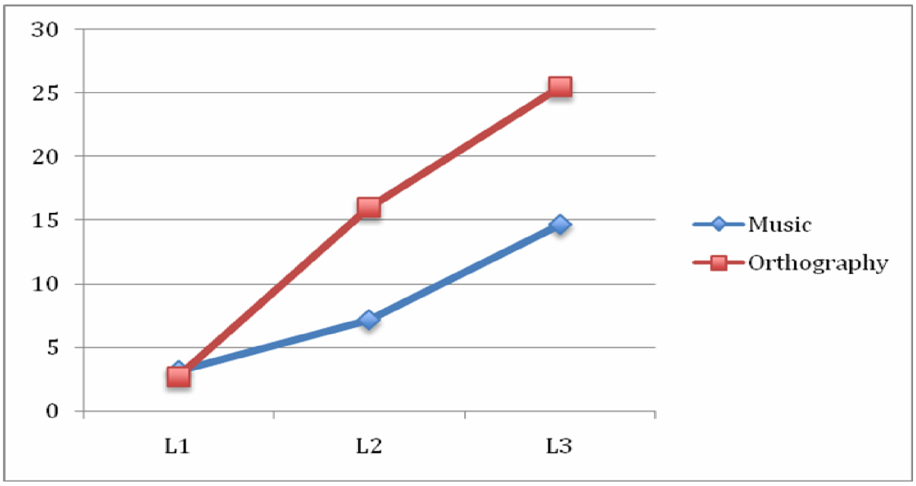


Figure 9. Number of signal units correctly generalized ("unseen")

A two-way independent MANOVA showed a significant main effect for language for both seen ($p = 0.021$) and unseen ($p < 0.001$) items. Effect of modality was significant for both seen ($p = 0.002$) and unseen ($p = 0.039$) items. There were non-significant interaction effects of language and modality for seen ($p = 0.0971$) and unseen ($p = 0.285$) items.

Discussion

Seen Items: In contrast to the results from study one, where each musical group failed to learn language 1, here, the orthographical participants had a mean of 16 signal units correctly reproduced, before performance increased dramatically in languages 2 and 3. The musical participants also increased dramatically in performance from language

1 to 2 to 3. This indicates that both musical and orthographical participants correctly learned and reproduced the system in place, although the orthographical participants were more successful from an initial high starting point at L1. The fact that L1 is random indicates than the orthographic participants were memorising the input in L1, and that this was more readily done in the orthographical language than the spoken one.

Unseen Items: Both musical and orthographical participants scored almost identically on L1, before each increased in performance in languages 2 and 3. Again, this indicates that both groups were able to correctly generalise to unseen items, once they had identified and learnt the system in place. However, again, orthography proved itself more easily learnt.

In summary, both orthographical and musical participants proved themselves able to both reproduce seen items and generalise unseen items. In particular, the ability to generalise unseen items was remarkably similar across modalities. This suggests that the systematicity bias, manifested in this ability, is similar in both modalities. Differences in performance, particularly in reproducing seen items, may be as a result of difficulty with production (a spoken word is often more easily reproduced than a musical tune), or the differences in literacy between modalities seen in section 3.2.

6.6.4. Structure of output compared to input

Across all languages, orthographically literate participants had higher weighted ratios than musically literate participants. In L1, orthographical participants had a weighted ratio of 0.044, whilst musical participants had one of 0.018. This pattern is seen in L2 and L3. In L2 the orthographical participants had a mean weighted ratio of 0.396, while the musicians had a mean weighted ratio of 0.048. In L3, orthographical participants had a mean weighted ratio of 1.736, compared to the mean of the musicians, at just 0.081. Figure 10 presents means for both groups and each language. This clearly shows that orthographical ratios were on average higher than musical ratios, rising dramatically from their almost identical value at L1.

A two-way independent ANOVA showed a significant main effect of language ($p > 0.01$). There was also a significant main effect of modality, ($p = 0.01$). Additionally, the ANOVA showed a significant main interaction effect of language and modality ($p = 0.01$). Figure 10 shows this clearly – the main effect of language can be seen in the differing values in each language. The main effect of modality is also clearly shown by the dramatic difference in estimated marginal mean between modalities.

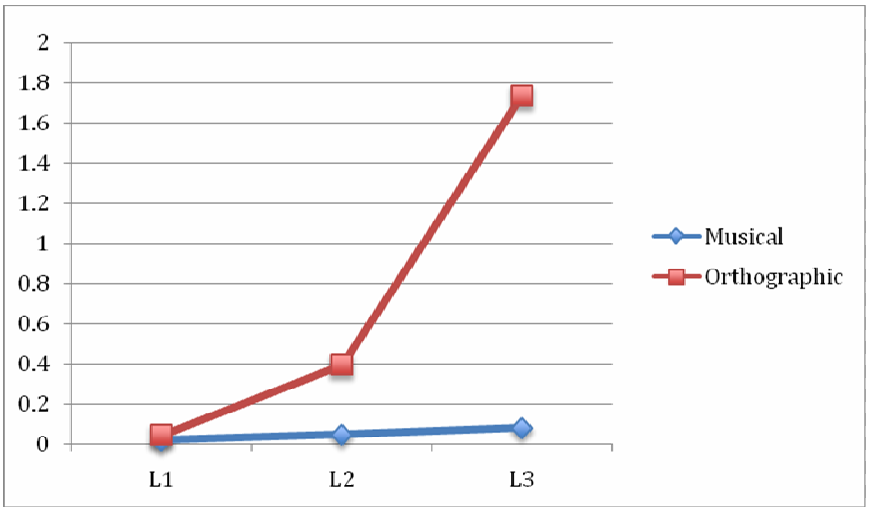


Figure 10. Weighed ratio of output compared to input

Discussion

Both orthographically literate and musically literate participants were sensitive to structure in their respective input languages. However, the orthographically literate participants proved much more successful in learning and reproducing this structure than the musically literate participants. This suggests that the orthographical language is more readily learnt than the musical one.

7. Summary of results and implications

7.1. Study 1 – Literacy

We used four methods of analysis on the data from each participant, in order to test our hypothesis that illiterate musicians would behave in a similar manner to non-musicians in a musical language learning task.

The measurement of compositionality of output language showed a main effect of language, with a non-significant effect of musical knowledge. However, a closer look at the data indicated an effect of musical knowledge, with musicians and illiterate musicians behaving in a similar manner, and non-musicians behaving much differently. Our analysis of the systematicity of output languages indicated that some musicians and illiterate musicians were able to learn and reproduce the systematicity in the input languages. However, no non-musicians were able to do so. Analysis of the similarity of form showed a significant main effect of music for both seen and unseen items – both musicians and illiterate musicians seemed to have been able to reproduce seen items and generalise unseen items, although musicians were more successful at this task than illiterate musicians. Non-musicians were largely unable to generalise unseen items, despite some success in reproducing seen items. This indicates that they had not learned the system in place. Having analysed the structure of output compared to the input, musicians proved themselves most sensitive to the structure of the input, while illiterate musicians were partly sensitive. Non-musicians did not appear sensitive to the structure, and the differing mean weighted ratios between groups were reflected by a significant main effect of musical knowledge.

From this evidence, it would appear that our hypothesis that illiterate musicians would behave like non-musicians has been disproven. In the first two methods of analysis (compositionality and systematicity of output languages), illiterate musicians behaved like musicians. In the final two methods of analysis (similarity of form, structure of output compared to input), whilst illiterate musicians did not pattern exactly with musicians, they were far from patterning with non-musicians. Thus, we may qualify Brown's (2008: 58) statement that "there are still strong indications that musical

literacy will induce a systematicity bias in a musical language learning task". It appears, rather, that literacy alone is not key to inducing this systematicity bias.
By extension, this could mean that "practicing language", i.e. speech, plays a larger part in developing metalinguistic awareness than previously thought, and that literacy is not key here, as has been suggested.

In some cases our statistical analysis presented us with non-significant effects of musical knowledge (e.g. compositionality of output languages) and language (e.g. structure of output compared to input). This was despite strong tendencies in the data which indicated significant effects. In these cases, we may conclude that the high individual variation and the small sample sizes used in this paper may have caused these non-significant results. Larger subject groups would be preferable in further studies, in order to test whether the non-significant effects found in the ANOVA are due to the small sample size. Additionally, the high individual variation seen in all groups in the present study might be lessened by a larger subject group.

7.2. Study Two – Modality

We used the same four methods of analysis in study 2, to investigate whether referential meaning is relevant to artificial language learning, and were presented with some quite robust results.

Our analysis of the compositionality of output languages showed a non-significant effect of modality, with a significant main effect of language. However, further study of the data indicates that orthographic participants performed on average better than musical participants in replicating compositionality in their outputs. This indicates an effect of modality. The data shows us that, while both musical and orthographical participants were able to reproduce compositionality, orthographical participants were much more successful. Analysis of the systematicity of individual's output languages showed that considerably more orthographical participants learned and reproduced systematicity than did musical participants. This gives strong support to the hypothesis than an orthographical (referential) language is more readily learned than a musical (non-referential) one. The analysis of similarity of form showed significant main effects of language, modality and interaction. Thus, both musical and orthographical participants were able to reproduce seen items and generalise to unseen items – in other words, both groups had learned the underlying system and could generalise to novel items. However, orthographical participants were more successful than musical participants in this task. In comparison of the structure in output and input, we found significant main effects of language, modality and the interaction of the two. Both orthographical and musical participants were sensitive to structure in their input. However, again the orthographical participants were more successful in learning and reproducing this structure.

Thus, it is clear from the above evidence that an orthographical (referential) language is more easily and readily learnt than a musical (non-referential) one. In all four methods of analysis, orthographic participants proved themselves more successful in learning and reproducing their respective languages. Again, the non-significant effect of modality in the analysis of compositionality of output languages may be explained by individual variation and small sample sizes. Thus, we may conclude that the hypothesis that referential meaning is irrelevant to artificial language learning has been disproven. The following section presents possible alternative explanations for this finding, and the findings of study 1.

7.3. Possible contributing factors to results

Whilst we have striven to control literacy effects by employing a musical language learning paradigm, this has proven difficult. It has been noted above (section 3.2) that musical literacy does differ considerably from orthographic literacy. Whilst an orthographically literate individual is likely to be highly proficient in both the passive (reading) and active (writing) aspects of literacy, this is not necessarily the case in musical literacy. In musical training, the passive aspect is largely concentrated upon, and the active aspect is largely taught at a later date. Whilst it is true that most musically literate children and adults may be able to transcribe or compose a short simple tune, this does not represent a similar level of "writing" in music as we see in natural language. Additionally, musically literate people almost always read music more than they write it. It can also be argued that musically literate people actually read music less than they do text (few exceptions to this exist – composers, for example). This suggests that the musical participants discussed in this dissertation may not in fact meet the literacy requirements needed in order to model natural language. Thus, the results described above may have been influenced by these literacy effects. It could prove useful to replicate the studies above (particularly study 2) using musicians who are highly literate (i.e. composers). It is hypothesised that these individuals may perform comparably with the orthographically literate participants, and thus further discussion into reference and meaning may be warranted. Furthermore, the behaviour of these highly literate musicians may differ from the "literate" musicians discussed above (study 1). Thus, the need to rigorously control for aspects of the experimental paradigm is exemplified here.

As was discussed above in section 4.2, literate musicians have been proven to use systematic practice strategies in learning a piece of music. It was suggested that this may furnish musicians with a systematicity bias. However, studies into practice strategies have largely focused on literate musicians in the Western Music repertoire. Thus, it would be informative to conduct a study into whether illiterate musicians use systematic learning strategies in a similar manner. This might inform our discussion of systematicity bias. I propose that illiterate musicians do indeed use systematic learning strategies. As Priest (1989: 175) states, "any 'analysis'…can…relate only to the sounds and to the kinaesthetic experience of having sounded them before, not necessarily to their graphic representation as musical notation". Furthermore, I propose that illiterate musicians would behave like the musicians in Bever and Chiarello's (1974) test of musical processing, i.e. processing a musical phrase as a series of analysable notes. Thus, literacy need not be in place for systematic practice strategies to work. Systematic practice strategies which are employed by musicians may differ from those employed by illiterate musicians, which may contribute to the difference in performance on language learning tasks. Furthermore, this use of systematic practice strategies is another distinct difference between musicians and orthographically literate individuals. This may account in part for the results found above.

Additionally, musicians make use of extra representational systems which are not available to non-musicians. These involve systematic motor patterns, and the visuo-spatial representation of hands on the instrument. This is often highly systematic, and may indeed contribute towards a bias towards systematicity. Furthermore, musical tunes are highly structured, with a distinct hierarchy in place. Most pieces which musicians are exposed to in their training fall under these highly systematic rules, and thus these may reflect a systematicity bias.

The results of study 2, in particular, may have been affected by the different forms of production used between modes. Both musical and orthographical participants seemed to note and replicate the systematicity in the input. However, the orthographical performance was much higher. This could be due to the fact that spoken words are often more easily reproduced than a musical tune – vocal reproduction of a tune is remarkably difficult.

So, it is difficult to pinpoint the exact cause or trigger of systematicity bias. It could indeed be as a result of a combination of factors – literacy, extensive practice, visuo-spatial representation, etc.

7.4. Implications

This paper has presented the results from two studies – one concerned with literacy, one with modality. Results from the first study suggest that literacy alone may not be sufficient for systematicity bias to be present. Illiterate musicians behaved like literate musicians in a variety of measures of language learning, unlike non-musicians, as had been hypothesised. As we have seen above, music and language share many aspects, and thus a musical language may be a useful substitute for a natural language in studies of this nature, where literacy is the factor under investigation. Thus, we might tentatively extend the findings of this study on musical languages to natural language, and conclude that literacy alone is not crucial for the development of the systematicity bias.

From an evolutionary standpoint, this implies that cultural evolution was, and remains, key to language acquisition, development and change. In other words, practice using the language, through speech, plays an important role. This practice may also account for the systematicity bias observed in this study – illiterate musicians exhibited this bias in learning and reproducing a systematic language.

Thus, the systematicity bias seen in text-based artificial language learning experiments (Kirby Cornish & Smith 2008, Tamariz & Smith 2008) may, in fact, be due to practice in, or exposure to, language, rather than literacy alone. Thus the results of this study, though surprising, refute the claim that systematicity bias is a result of orthographical literacy alone. A further study, using similar participants and languages in an iterated learning paradigm, could illuminate how this bias develops, and how quickly it alters the input language.

Of course, it is always problematic to extrapolate from experimental results, and apply them to evolutionary scenarios. We must ask ourselves whether modern humans are suitable for use in testing evolutionary theories. The participants used in the above studies are all language users. Could it be that we humans have adapted towards systematicity? In early human linguistic development, perhaps some minor systematicity in the linguistic environment may have triggered a bias towards this very systematicity, and caused early humans to apply it to the language in place, thereby creating a yet more systematic language. However, it is true that we can only work with what we have to hand – it is impossible to state exactly what the language practices of our early ancestors might have been, and so we must use modern humans in an attempt to address this mystery. As such, the statement by Cornish, Tamaríz and Kirby (In press: 10) seems apt in this case: "our experiments should not be taken to be a 'discovery procedure' for uncovering our evolutionary ancient learning biases but rather as a tool for understanding the fundamental adaptive dynamics of the cultural transmission of language".

The second study, regarding modality, yielded robust results that suggest that referential meaning really is key to artificial language learning – orthographically literate participants performed much better on a spoken language learning task than did musically literate participants on a musical language learning task. These particular groups were selected to control for literacy and practice factors – all members of each group were literate and practiced in their respective modality. However, as seen extensively above, literacy may not have been adequately controlled for. The greatest difference between groups, and thus the variable of interest, was meaning. Orthographically literate participants were familiar with pairing reference and signals. In orthographic languages form and referential meaning are paired, while in musical languages, form is paired with emotional meaning. Although music can be very emotionally meaningful for musicians and non-musicians alike, it does not carry referential meaning. Thus, from the results discussed above, it could be argued that, as referential meaning is indeed relevant to learning an artificial language learning experiment, there is little justification for using a musical language as a model for natural language.

However, as we have seen above, musical participants are literate in a different way to orthographic participants. Thus, literacy effects may be relevant here. The musical and orthographical participants may indeed be learning in a different way, as these literacy effects are difficult to control for. This could contribute towards the results found. Furthermore, the musical and orthographical participants had to respond in different forms – singing and speaking, respectively. Thus, production effects could also contribute to effects found. So, we cannot at this point invalidate the results of artificial language learning experiments which use a musical language paradigm, rather we must consider the literacy effects in place here, and attempt to control as best we can for them, for example by using musicians who most closely resemble literate speakers, i.e. composers, in further studies.

8. Conclusion

This dissertation has presented the results of two experimental studies. The results of the first question the possibility that systematicity bias in language results from literacy, instead suggesting that extensive practice in language, amongst other aspects, may trigger a bias towards it. Proposed literacy effects in ALL studies may now be seen in a new light. Assumptions that literacy is key to language may be ill-informed. Thus, linguists must take care to clarify which aspect of language they wish to study, and the data they will use to do so. However, cultural transmission is still key to this systematicity bias, as experience with systematicity in language triggers the systematicity bias, thus altering language for the successive cultural generation of learners. The second study questions the view that non-referential artificial languages are just as readily learnt as referential ones. However, literacy and production effects may have impacted upon these results. So, reference may indeed be relevant to artificial language learning, and thus, we must be careful when using musical language as a model for natural language.

In conclusion, this dissertation has highlighted the need to empirically investigate possible triggers of the systematicity bias, in order to pinpoint whether literacy truly is causing perceived effects, or whether some other factor is impacting upon results. fFurther studies with larger participant groups and rigorous experimental controls may prove useful to investigate this phenomenon. Furthermore, referential meaning has been proven to be relevant to artificial language learning. This finding highlights the need to seriously consider meaning and to control for other aspects such as literacy and production mode when modelling language evolution.

Appendix I

Musical Languages

Bold indicates a tune was included in the learning bottleneck (or "seen" items)

Language One

	Blue			Yellow			Red			
○	7	-12	-5	**12**	**-5**	**-12**	12	-12	0	★
	4	4	11	**-1**	**-12**	**-5**	-5	-1	-8	●
	-12	11	-8	11	-12	4	0	7	12	✚
⬡	11	-1	4	**7**	**0**	**-12**	**-8**	**11**	**-1**	★
	-1	**12**	**4**	**0**	**12**	**-1**	4	0	-8	●
	11	**12**	**-5**	**-8**	**7**	**0**	-12	11	-1	✚
□	**-12**	**4**	**-5**	**12**	**-1**	**-12**	**11**	**-5**	**12**	★
	-12	**8**	**11**	**-12**	**12**	**0**	**4**	**-12**	**0**	●
	-5	12	0	-1	0	4	4	-1	0	✚

Language Two

	Blue			Yellow			Red			
○	-12	-5	-1	**4**	**-5**	**-1**	**-8**	**-5**	**-1**	★
	-8	11	7	4	-5	7	**-12**	**-5**	**-12**	●
	-8	-5	12	**4**	**-5**	**12**	**-12**	**0**	**12**	✚
⬡	**-8**	**0**	**-1**	4	0	-1	**-12**	**0**	**-1**	★
	-8	**0**	**7**	4	0	7	-12	0	7	●
	-12	**0**	**12**	**4**	**0**	**7**	-12	0	12	✚
□	**-8**	**11**	**-1**	4	11	-1	**-12**	**11**	**-1**	★
	-8	11	7	4	11	7	**-12**	**11**	**7**	●
	-8	**11**	**-1**	4	11	12	-12	11	12	✚

Language Three

	Blue			Yellow			Red			
○	-8	-5	-1	4	-5	-1	**-12**	**-5**	**-1**	★
	-8	-5	7	4	-5	7	-12	-5	7	●
	-8	-5	12	4	-5	12	**-12**	**15**	**12**	✚
⬡	-8	0	-1	**4**	**0**	**-1**	**-12**	**0**	**-1**	★
	-8	0	7	**4**	**0**	**7**	**-12**	**0**	**7**	●
	-8	**0**	**12**	4	0	7	**-12**	**0**	**12**	✚
□	**-8**	**11**	**-1**	**4**	**11**	**-1**	**-12**	**11**	**-1**	★
	-8	**11**	**7**	**4**	**11**	**7**	-12	11	7	●
	-8	11	12	4	11	12	**-12**	**11**	**12**	✚

Appendix II

Spoken languages

Mapping from musical interval to spoken syllable:

Interval	Syllable
C4 – E4 = 4 semitones	mu
C4 – G4 = 7 semitones	ga
C4 – B4 = 11 semitones	di
C4 – C5 = 12 semitones	ki
C4 – C4 = 0 semitones / unison	na
C4 – B3 = -1 semitones	be
C4 – G3 = -5 semitones	tu
C4 – E3 = -8 semitones	pe
C4 – C3 = -12 semitones	lo

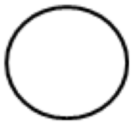
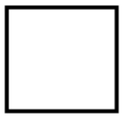
Spoken Languages

Bold indicates that the word was included in the learning bottleneck (or “seen” items)

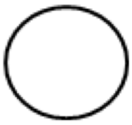
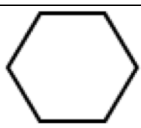
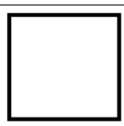
Language One

	Blue	Yellow	Red	
◯	ga lo tu	**ki tu lo**	ki lo na	★
	mu mu di	**be lo tu**	tu be pe	●
	lo di pe	di lo mu	na ga ki	✚
⬡	di be mu	**ga na lo**	**pe di be**	★
	be ki mu	**na ki be**	mu na pe	●
	di ki tu	**pe ga na**	lo di be	✚
□	**lo mu tu**	**ki be lo**	**di tu ki**	★
	lo pe di	**lo ki na**	**mu lo na**	●
	tu ki na	be na mu	mu be na	✚

Language Two

	Blue	Yellow	Red	
	lo tu be	**mu tu be**	**pe tu be**	★
	pe di ga	mu tu ga	**lo tu ki**	●
	pe tu ki	**mu tu ki**	**lo na ki**	+
	**pe na be**	mu na be	**lo na be**	★
	pe na ga	mu na ga	lo na ga	●
	pe na ki	**mu na ga**	lo na ki	+
	**pe di be**	mu di be	**lo di be**	★
	pe di ga	mu di ga	**lo di ga**	●
	pe di be	mu di ki	lo di ki	+

Language Three

	Blue	Yellow	Red	
	pe tu be	mu tu be	**lo tu be**	★
	pe tu ga	mu tu ga	lo tu ga	●
	pe tu ki	mu tu ki	**lo tu ki**	+
	pe na be	**mu na be**	**lo na be**	★
	pe na ga	**mu na ga**	**lo na ga**	●
	pe na ki	mu na ki	**lo na ki**	+
	**pe di be**	**mu di be**	**lo di be**	★
	pe di ga	**mu di ga**	lo di ga	●
	pe di ki	mu di ki	**lo di ki**	+

Appendix III

Questionnaire (Musical languages)

1.
How difficult would you rate the task of learning the musical language (on a scale of 1 – 5, 1 being easy, 5 very difficult)?

2.
How did you go about trying to learn the language?

3.
Did you notice any patterns in the tunes and meanings?

4.
How confident were you that you knew the correct tune for each meaning?

5.
Did you recognise all the meanings/ pictures you saw during the testing phase?

6.
If you couldn't remember the exact tunes during testing, did you try to use a pattern of some kind?

Questionnaire (Spoken languages)

1.
How difficult would you rate the task of learning the spoken language (on a scale of 1 – 5, 1 being easy, 5 being very difficult)?

2.
How did you go about trying to learn the language?

3.
Did you notice any patterns in the words and meanings?

4.
How confident were you that you knew the correct word for each meaning?

5.
Did you recognise all the meanings/ pictures you saw during the testing phase?

6.
If you couldn't remember the exact words during testing, did you try to use a pattern of some kind?

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