MA Thesis
Statistical Learning: the Relationship Between Seeing Patterns and Speaking Languages

Annabel Matser
s2608553

Departments of Applied Linguistics and Frisian Language and Culture
Faculty of Arts
University of Groningen

Supervisor: Dr. Hanneke Loerts
Second reader: Dr. Merel Keijzer
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Abstract

In any language, there are some regularities to be found: some words or sound sequences are more likely to follow one another than others. Using the regularities of a language is called 'statistical learning'. Although there have been a lot of studies on how human beings use statistical learning, most of these studies did not examine whether or not there was a correlation between the number of languages a person knew and the ability of learning patterns. This is why this study focusses on this question, to fill in the gap in the current literature. The expectation was that people who know more languages would also be better at noticing the statistical structure in an artificial, nonverbal statistical learning task. Furthermore, this study also analysed the reaction times of the participants to examine whether people who know more languages are also be quicker in noticing the structure. Lastly, it was also looked at whether other factors may have had an influence on the accuracy score of the participants: the influence of age of acquisition of the foreign, methods of learning, feeling multilingual, their perceived ability of language learning, the number of languages used on a daily basis and gender.

An experiment in E-prime was used: participants were exposed to a continuous stream of figures for two and a half minutes, in which pairs of figures were hidden. After this, they had to choose whether or not they had seen the figures in that order in the stream. Their score was calculated on the basis of the correct answers.

The results went against the expectations: there was no correlation found between the number of languages a person knows and the ability of seeing patterns. This also brings down the expectation of the participants who knew more languages being quicker in seeing the structure. Indeed, there was also no correlation between the number of languages and the reaction time of the participants. The other factors did not seem to have an influence on the accuracy scores of the participants, there seemed to be only a difference between gender: on average, women scored higher than men in this experiment. Another interesting result was that people who knew three languages seemed to be better in seeing patterns than the participants who knew more or less languages.
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1. Introduction

“I do not have a talent for learning languages” is a sentence one may often hear when talking to others about learning a new language. Many people think that speaking a lot of languages is a talent, or something that a person is born with: some people are naturally good at learning languages while others are doomed to struggle. Although it might be true that not everyone is equally good at picking up a language, this may be explained by something else than ‘being talented’.

Starting to learn a new language without having any experience with this language, is quite hard for everyone in the beginning. Especially when listening to unfamiliar languages, it will be difficult to understand anything. One problem when facing a new language is that one does not know when one word stops and when another word starts, in other words, where the word boundaries can be found in the speech stream. Unlike in texts, in which we are able to see clear spaces between words, there is no such obvious information about word boundaries in oral speech. Although the information might not be very obvious and may even be quite hard to notice, there might be a way of differentiating words from other words in oral speech when one does not know the language. Studies have shown that people of all ages are able to recognise words in a continuous speech: they can do this because of the statistical structure of the language (Saffran, Aslin and Newport, 1996; Saffran, Johnson, Aslin and Newport, 1999). Most of the time, people are not aware of this, but due to the probability of one word (or a piece of a word) following another, people may remember this structure. For example, eight-month-old children have been shown to be able to learn and remember three-syllable-strings which had high transitional probabilities (Saffran et al. 1996), in other words, syllables which were very likely to follow one another. Remembering this structure (although often unconsciously) and being able to apply it afterwards is called statistical learning.

1.1. Research question

This research is about being able to see patterns, it aims to look at a nonverbal statistical learning task. Learning a new language might be easier when one is able to see patterns, as all languages have a certain structure. Statistical learning is used by people when learning a new language. As statistical learning is about extracting knowledge from previous experience and seeing regularities, we may think that the more languages one knows, the easier it will be to see patterns in a continuous stream, because the knowledge of one language can be used in order to learn a new one: people may be able to apply what they already know when learning something new. Experience seems to be important when it comes to statistical learning: according to Kovács and Mehler (2009), early life experience, as being raised bilingual, may cause the children to be “more flexible at learning speech structures than monolinguals”. Bilingual children need to learn “twice as much about language than their monolingual peers”, but the bilingual and monolingual children have approximately the same speed of acquisition. This suggests that bilinguals are able to learn two languages as fast as monolinguals learn one language. On the other hand, this way of thinking may also
be reversed: those who are better at statistical learning may also want to learn more languages. It may be easier for people who are good at statistical learning to learn more languages.

Much research has been done on the topic of statistical learning, but, as far as the researcher knows, not on the topic of whether multilingualism stimulates the process of seeing patterns. Therefore, the question that will be addressed in this study is: “is there a relationship between the number of languages a person knows and their performance in a visual, nonverbal statistical learning task?” In order to answer this question, this study will look at the following sub-questions: do people who know more languages have a higher accuracy score? Are people who know more languages faster in responding than the people who know less languages? What other aspects may influence their performance in such a task? To answer these questions, an experiment among multilingual students of the University of Groningen and the Hanze University of Applied Sciences was done in order to see whether people who knew multiple languages were indeed advantaged when it comes to a visual, nonverbal statistical learning task. Thirty-one students were exposed to an artificial, nonverbal statistical learning task, but no information about the aim of this study was given: participants did not know they were exposed to a task which was about seeing patterns. After this, they were tested on their ability to recognise these hidden structure. Beforehand, participants also did not know they would be tested on this.

This study will not focus on the question whether multilinguals are better than monolinguals, but on the relationship between knowing a number of languages and seeing the patterns in a statistical learning task.

Testing people who are multilingual may raise the question of when someone is considered to be multilingual, in other words, when does one actually know a language? As will be explained in further detail in chapter 2, in this study, the definition of when someone knows a language is based on the definition by Grosjean (1989): a bilingual is someone who “has developed competencies [...] to the extent required by his or her needs and those of the environment” (p.6). Therefore, in this study, one has to be able to have an everyday life conversation in their additional language(s) in order to acknowledge that they know a language.

1.2. Why is this study important?

As Saffran et al. (1996) have found that statistical learning may be used in order to discover word endings in a spoken language, it may be thought that statistical learning is in fact an important tool when it comes to learning a new language. If people who know more languages are indeed better at noticing a hidden structure in a statistical learning task, it may mean that they are able to extract a structure faster as compared to people who know less languages. This may mean that they are also able to see a structure in languages faster. They may not only be able to notice words in speech faster than people who know less
languages, but also grammar and syntax. This may suggest that learning languages may be easier for someone who already knows multiple languages. This can be an advantage for a person who knows multiple languages, because nowadays, knowing multiple languages is important to be able to communicate. It may stimulate people who know more languages to learn even more, as it may be easier for them. This is important, because people often speak about the disadvantages of speaking multiple languages and the results of this present study might add to the advantages of knowing multiple languages. We already know that being bilingual may enhance cognitive advantages (Bialystok, 2009), but if people who know multiple languages are indeed better at statistical learning, this is yet another advantage, which may stimulate people to learn another language. Furthermore, if the results of this study suggest that knowing multiple languages enhances statistical learning, it may be used to adapt learning materials: people who know more languages could make use of statistical learning when they want to learn a new language. Learning languages may become easier and more accessible for everyone.

1.3. Content

This paper is divided into five parts: after the introduction, more information and definitions about the topic will be given in chapter 2. This theoretical background serves at acquiring more knowledge about the statistical structure of a language and statistical learning, but also a broader definition of what it means to know a language will be given. In order to have a complete image of statistical learning, there will also be given some examples of previous studies in this chapter. After having drawn a clear representation of all definitions and previous research, the methodology of the present study will be given in chapter 3. In this methodology, participants, materials and the procedure of the testing phase will be exposed. The results of the analysis of the data gathered during the testing phase will be shown in chapter 4. After this, these results will be discussed and a conclusion will be drawn according to these results. The references can be found at the end of this study, as well as the appendix.
2. Literary background

In this chapter, a definition of the statistical structure of language will be drawn from several definitions by researchers, such as Eugene Charniak and Saffran, whom both have done a lot of research in the field of statistical language learning (Eugene Charniak’s Home Page and Jenny Saffran). It is important to know about the statistical structure of a language, because it may be related to why people who know multiple languages are better in statistical learning than those who have less experience in learning languages (as they have encountered less structures). After this, a few examples of who uses statistical learning and in what situation will be given mainly through previous studies by Saffran, et al. (1996;1999) and Fiser and Aslin (2002). In this chapter, there will also be given a broader definition of multilingualism in order to determine when the participants of this study were able to state that they know a language.

2.1. What is the statistical structure of a language?

According to Saffran et al. (1996), people may be able to recognise words in oral speech when hearing an unknown language. Word boundaries can be defined in oral speech by “the statistical information contained in sequences of sounds” (p.1927), in other words, the statistical structure of this unknown language. Saffran et al. (1996) argue that in speech, “measurable statistical regularities” (p.1927) are present, which differentiate the recurring sound sequences within a word from the accidental sound sequences that can be noted between word boundaries. That is to say, sounds which occur within a word are more frequent than accidental sounds between two words (the last sound of one word and the first of the next word). These statistical regularities between two sound sequences are called 'transitional probabilities’, as they define the probability of the transition between two sound sequences. According to Saffran et al. (1996), in any language, it is more likely that the transitional probability of two sound sequences is higher when the two sounds follow each other within a word. When the two sound sequences between two words follow one another, it is more likely that the transitional probability is lower. People are able to recognise the word boundaries thanks to the transitional probabilities and the “types of structures exemplified in linguistic systems” (p.1927). This will be discussed into detail in the next section.

The results of the study conducted by Saffran et al. (1996) suggests that language is made out a statistical structure, thanks to which we are able to differentiate different sound sequences within and between words in oral speech. In the next few sections, a broader definition by different researchers will be given in order to create a clear view on the statistical structure of a language.
2.1.1. Statistical model and probability theory

Although statistical learning has already been discussed before the early nineties, Eugene Charniak published a useful book in 1993 called *Statistical Language Learning*. In this book, he designed a model concerning statistical learning in language acquisition. Although Charniak works a lot with mathematical equations, his theory can also be understood without these equations and, in order to make his point as clear as possible in written text, this section will leave out the equations of the probability theory.

First of all, probability theory is an important subject in statistical learning. Charniak describes probability theory as opening a book at a random page and pointing at a random word: all words of the language in which the book is written is possible to point at (p.21), but words that occur more often are more likely to be the word that one points at. Charniak wants to assign probability theory to explain the statistical structure of a language. The statistical structure of a language is of course not about pointing at a word, but as Charniak also describes in the same chapter, a statistical model “has only one requirement […] it must assign a probability to all possible sequences of words” (p.24). Charniak gives the example of the sentence: “Jack went to the…” and the possible words that follow are “hospital”, “pink”, “number” and “if” (p.25). Each of these words have their own probability of how plausible it would be to be the last word of the given sentence. The probability of one word following the next is known as “transitional probabilities”, as we have seen before. Thompson and Newport (2007) argue that these transitional probabilities are calculated thanks to the frequency of how often they are used in a given language. For example, in English, the probability of “pre” being followed by “ty” is 80% percent in “infants language environments” (Xie, 2012, p.27), as there are a limited number of syllables which may follow afterwards.

This is not only true for words at the end of the sentence, but also holds for other words in other positions within the sentence. For this, Charniak gives the example of: “the … dog” and the possible words that might fill in the gap were “big” and “pig” (p.25). It is only thanks to the third and last word (“dog”) that we know which of the two words is able to fill up the gap, as adding 'pig' to the middle of the sentence does not make any sense here. The probability of “big” being the word that comes before “dog” is much higher than the probability of it being the word “pig”. “The word ‘dog’ selects ‘big’ over ‘pig’” (p.25). Statistical structure is not about counting how often a word appears in a text, but it is about the probability of a specific word following another word, whether it is at the beginning of a sentence, in the middle or at the end.

The statistical structure is not only about one word following the next as we just have seen, but it also works for syllables within a word. For example, if the sequence 'ele' is spoken, the first sequence that comes to people's mind is 'phant' or 'vator' (Saffran, et al. 1999), because in English, these are the other parts of
the words that make up a word starting with 'ele'. It also works the other way: there are some parts of words or a few letters in any given language that have a low probability of following each other. We may see this in another example by Xie (2012): in the phrase “pretty baby” (p.27), the syllable “ty” may be followed by numerous amounts of syllables, because the following syllable is the beginning of the next word. There is thus a very low probability of “ty” being followed by “ba”: approximately 0.03% in the language environment of infants. According to Xie (2012), thanks to the transitional probabilities, we know that “pretty” is more likely a word than “tyba” (p.27).

Ellis, O’Donnell and Römer (2013) also acknowledge the statistical structure of languages, and state that "language knowledge involves statistical knowledge" (p.167), as language is full of frequency patterns. Ellis et al. (2013) call these frequencies “type frequencies” (p.167). There are certain words, parts of words, conjugations, semantics, or basically every grammatical structure that can be found in language, which have a higher or lower frequency. In other words, some structures are used more often than others: type frequency is “the number of distinct lexical items that can be substituted in a given slot in a construction” (p.167). In the study by Ellis et al. (2013), the example of ‘–ed’ is given: it is more likely that a verb is followed by ‘–ed’ in the past tense than that an irregular form is used (for example ‘swim’ to ‘swam’) (p.167). The higher the type frequency, the more likely it is to occur in a language. This is thus similar to the transitional probability we have seen before. Statistical structures with a higher frequency are likely to be more easy to learn than lower frequency structures, as it is easier to learn something when one encounters it more often. According to Ellis et al. (2013), “the more times we experience something, the stronger our memory for it, and the more fluently it is accessed” (p.167). When one encounters something more often, the memory of this will become stronger and it will be easier to access the information. This is also what Lany & Gomez (2008) found in their study: according to them, “prior experience can bootstrap infants’ learning of difficult language structure”. They investigated this with an artificial language either with or without adjacent dependencies between word categories (p.3). The infant participants were then exposed to new nonadjacent dependencies. They found that children of 15 months are able to learn the nonadjacent dependencies due to their short-term memory (p.5). This suggests that “learning mechanisms are powerfully affected by experience”.

Similar results were found by Lew-Williams and Saffran (2012), who found that “infants used prior knowledge experience to quickly narrow in on the most accurate analysis (p.6).” In this study, monolingual children from 9.0 to 10.9 months old were exposed to either bisyllabic or trisyllabic non-sense words. They were then exposed to four new non-sense words, two of those were low-frequency words and two were high-frequency words. Infants were either exposed to words of the same length or to words with a different length than in the previous phase. After this, they were tested: a word was repeated until the child looked away from the flashing centre light (p.4) for two seconds or after 20 seconds of looking at it (this is similar to Saffran et al., 1996). The children were able to distinguish “words and part-words when pre-exposure
and target words were consistent in length.” (p.5)

Therefore, we may wonder if knowing multiple languages, in other words, using more languages more frequently, helps to see the statistical structure of a completely new language in a quicker way. As multilinguals have more experience in using and learning a language, we may expect this to be true.

Furthermore, Charniak states that people's intuitions are often quite close to the real probability of one (sequence of a) word following another. In fact, according to him, it has been proven that people's intuitions are often more accurate than “any of the statistical methods currently available” (p.25). One may thus know which word comes next in a given language thanks to that person's intuition because of their knowledge of that language. However, it is not very probable that this will happen when someone hears a new language. When they do not have much knowledge of a language, it is not likely that they will know which word to use to fill up a gap, while still making a correct sentence. We may think that people will first have to learn about the statistical structure before they know which word is the correct answer, for example in the example “the … dog” (p.25). People who do not know about the grammatical structure of English (in this case) do not know which word may fill up the gap.

As we have seen, the statistical structure of a language is the probability of one word, a sequence of a word, a simple sound or in fact any grammatical structure of a language following another. These structures are recurring and can be found in every linguistic system. Every human being should therefore be able to extract these statistical regularities and learn from it. Statistical learning, as this is called, may be applied by human beings in order to learn these regularities and therefore, being able to differentiate between words and non-words (for example the last syllable from a word and the first of the next word). It is argued that this statistical structure of any given language is used to learn languages. In fact, this is also how it works when infants are starting to learn to speak: it is argued that even eight-month-old children use this way of learning a language (Saffran et al. 1996). Gomez and Gerken (2000) argue that children have “a fairly sophisticated statistical learning mechanism” (p.181).

In the next section, we will see how statistical learning may be applied by whom and in what situation, through studies which have been carried out before.
2.2. When is statistical learning used?

2.2.1. Statistical learning and language acquisition

Saffran et al. (1996) have laid the foundations of statistical learning in language acquisition. Their method has been the basis for many other studies, like the one by Saffran, Aslin and Newport (1999) and Abla and Okanoya (2009). The study by Saffran et al. (1996) was the first to discover that human beings are able to use the statistical structure of a language in order to learn it. As the aim of the present study is to know whether or not multilinguals are better in discovering the structure of a language, it is necessary to understand how these findings have been discovered.

Although statistical learning in language acquisition was already spoken of before, Saffran, Aslin and Newport were the first to apply this way of learning in the process of language acquisition in their study *Statistical Learning by 8-Month-Old Infants* (1996). They asked the question whether eight-month-old infants can distinguish word boundaries in a continuous speech. The eight-month-old infants were exposed to a continuous speech stream in which they would hear nonsense words, which formed an artificial language. There was no information given about the word boundaries, the only indication of the existence of these boundaries were the transitional probabilities: 1.0 within words and 0.33 between words. In other words, the chance of one syllable following another between words equals 100 percent, while between words, this equals 33 percent. As seen before, transitional probabilities are calculated thanks to the frequency of one (sequence of a) word following the next. For example, in the artificial word “bida” (p.1927), the transitional probability of “bi” being followed by “da” is 1.0, or 100 percent. The probability of one syllable following another one between words is 0.33: for example, there is a 33 percent chance that “ku” is followed by “pa” (p.1927).

After being acquainted to the words of this artificial language, the eight-month-old infants were exposed to two words of this language, and two non-words (words with the same syllables as the actual words from the artificial language, but which were not in the same order as the real words. The non-words were not present in the continuous stream). There was a clear difference between how long the infants listened to the words and to the non-words: the children needed more time to listen to the new, non-words (8.85 seconds) than to the familiar words (7.95 seconds), as they were not yet familiar with these words. The listening time was measured thanks to the “sustained visual fixation on a blinking light” (p.1927) of the infants: the three-syllable-string was repeated until the child looked away for two seconds or until the child had focused on the light for fifteen seconds (p.1928).

This shows that eight-month-old infants are capable of extracting statistical information of a new (in this case artificial) language. Even if the children were only eight months old, they were already able to distinguish between the words and non-words. This suggests that in ‘real’ speech, children as young as eight
months are probably also able to distinguish different words. In this case, they were able to do so even after only two minutes of exposure to the new language, suggesting that this mechanism of learning is quite effective. This also suggest that “language input” (p.1926) is very important for children in order to learn a language, as this exposes them to the structure of this language. If they already learn that much from two minutes, we may say that this structure is important to form a good knowledge of the language.

The statistical structure of a language is very much present in a language. People of all ages make use of the structure to know where boundaries are. Not only words or sequences of words are concerned by statistical learning. It has also been proven that grammatical structures can be learned with this method. According to Aslin and Newport (2012), statistical learning is also used when learning general rules. Gomez and Gerken (1999) indeed found that one-year-old children were “able to discriminate new grammatical from ungrammatical strings” (p.130) after two minutes of exposure to the grammar. Furthermore, Thompson and Newport (2007) argue that “statistical learning may play a role in the acquisition of higher-order levels of language” (p.39), for example in syntax. This may mean that human beings not only use statistical learning when it comes to word boundaries, but also for other structures that are hidden in a language, such as grammar and syntax.

2.2.2. Statistical learning does not only apply to linguistics

We may wonder whether this way of learning may only be used in situations like in the study of Saffran et al. (1996): understanding sounds in an artificial language. Saffran et al. (1999) investigated whether statistical learning is only linked to linguistics, or whether people may also distinguish the statistical structure of non-linguistic sounds. In order to analyse this, they performed almost the same test as in the study by Saffran et al. (1996), only not with words and non-words, but with tone words. Instead of syllables (like they did in 1996), the study in 1999 used musical tone words. As in the other study, the tone words were presented in a continuous stream and no information about the tone words was given, the statistical structure was the only way participants would be able to know which part of the stream were the tone words. The test was done by both adults and eight-month-old children. The participants performed as well on this test as they did in the speech segmentation task by Saffran et al. (1996b) (in this study, they exposed adults to an artificial language and they were also able to distinguish words (p.618)). The results of the 1999 study suggest that statistical learning is not only used by humans to distinguish multiple words, in other words, it is not only used in the field of linguistics, but also with musical notes. Therefore, people are probably able to distinguish not only sounds from one another, but they may also be able to distinguish everything that has a statistical structure.

The results explained above show that statistical learning not only applies to linguistics: we may
hypothesise that human beings are able to discover a pattern in something else than a continuous speech stream. We may thus wonder if it is not only bound to listening to a language, but maybe also to seeing a ‘language’.

2.2.3. **Statistical learning of visual stimuli**

People thus tend to use statistical learning when hearing sounds of a new language. Although it has been proven that people are able to distinguish words from a continuous monotone speech stream (Saffran et al., 1996), there has also been research about statistical learning of visual stimuli. In their study, Fiser and Aslin (2002) tested nine-month-old children on how they responded to the statistical structure of an artificial nonverbal statistical learning task. Other than the study by Saffran et al. (1996), they used visual stimuli instead of auditory. They exposed the infants to a number of coloured shapes with a statistical structure in it. The experiment was quite similar to the one by Saffran et al. (1996), not only in its structure, but also because the children were almost the same age. In the visual experiment, there were twelve coloured shapes, divided into four base pairs and four noise elements: two elements composed one base pair, and the last element represented noise elements. Each noise element was assigned to a specific base pair and may be placed at any four sides of the base pair. Thus, it is possible to make four different scenes of one base pair and its noise element. As there were four different base pairs, sixteen different scenes were presented in this study. First of all, these sixteen scenes were presented in the habituation phase, in which the infant only had to look at the shapes. The child’s attention was drawn through sound effects. No information about the statistical structure was given, however, only the structure of element co-occurrences could be an indication of the statistical structure. Each scene was presented multiple times in order for the children to familiarise with them. After this habituation phase, the test phase began: two base pairs (without the noise element) and two non-base pairs (one element of a base pair and the corresponding noise element) were shown. To see whether children can discriminate between the base pair and the non-base pair, the time they were looking at the two pairs was measured. This was done with the use of a video system monitored by an observer invisible for the child (p.15822). Each child was tested individually on the parent’s lap. The result of this study showed that the children paid more attention to the base pair than to the non-base pair, suggesting that the child does learn the statistical structure of visual stimuli after being exposed to it.

A similar experiment was conducted by Abla and Okanoya (2009), in which they also exposed participants to visual patterns. The experiment was a little bit different than the one by Fiser and Aslin (2002): the length of the exposure was 6.6 minutes and they used triplets instead of pairs. Furthermore, instead of measuring the time that the participant looked at the figures, the participants had to press button one (the familiar
triplet was presented first) or two (the familiar triplet was presented second). This was different from the study by Aslin and Fiser (2002), as Abla and Okanoya worked with adult participants. Pressing buttons would not have been possible with nine-months-old children. Although the experiment had some differences, Abla and Okanoya also found that adults learned the triplets containing statistical structure. In fact, the mean performance was 72.2% (p.185), which is quite high. These results thus again confirm the idea that both adults and children are able to learn linguistic and non-linguistic structures thanks to the statistical structure.

2.3. What does it mean to be a multilingual person?

As this study is about the relationship of the number of languages a person knows and the ability of learning the statistical structure, it is important to know what being multilingual means and when someone may say that they know a language.

According to Charlotte Kemp (2009), most researchers agree on the fact that being multilingual means that one is able to speak three or more languages. If one speaks only two languages, we speak of a bilingual person. It is important to have some kind of definition when writing about multilingualism. The most important question is: when can one be considered as multilingual? And when is one able to say that they know a language?

There have been many definitions given to the concept of bilingualism or multilingualism. An example of a strict definition of bilingualism is given by Leonard Bloomfield in his book *Language*, published in 1933. He argues that “in the cases where this perfect foreign-language learning is not accompanied by loss of the native language, it results in *bilingualism*, native-like control of two languages” (p.55-56). In other words, one can only be bilingual when they speak their second language as well as their native language, and thus master their second language perfectly. However, this also means that it is difficult to become a bilingual person, as “after early childhood few people have enough muscular and nervous freedom or enough opportunity and leisure to reach perfection in a foreign language” (p.56). Although it is possible to be a bilingual or multilingual person according to Bloomfield (1933), many people who would consider themselves as multilingual might not be considered as such by this definition.

There are people who do not agree with this definition and even think that the whole opposite is true. For example, Bialystok (2001) states that “the idea of an 'uncontaminated' monolingual is probably a fiction” (p.1). Furthermore, Edwards (1994) believes that "everyone is bilingual" (p.55) and that even some kind of mastery of a language is enough to call oneself bi- or even multilingual. He argues that, if one can say a few
words in a foreign language ("c'est la vie or gracias or guten Tag or tovarisch" (p.55)), it shows that one has some command in a foreign language. According to Wei (2008) one can be an active multilingual (speaking and writing) or a passive multilingual (listening and reading). For these definitions, the opposite of Bloomfield's theory is true: many people who would not consider themselves as multilingual might be considered as such by this definition.

The definition of a multilingual person that will be used in this paper is none of the previously stated definitions, but aims to be a happy medium: it is the definition as given by Grosjean (1989): someone who “has developed competencies [...] to the extent required by his or her needs and those of the environment” (p.6). This definition has the advantage of both definitions stated before: not everyone may be counted as a bilingual (as opposed to Edwards), but it is not almost impossible to become a bi- or multilingual speaker after early childhood (Bloomfield, 1933). Therefore, in this research, the participants will have to be able to use all their languages in everyday life, however, they do not have to be native-like in all the languages that they speak.

2.4. Statistical learning and bilingualism

As we have seen so far, a lot of research has been done about the role statistical learning has in the field of language acquisition: distinguishing word boundaries, tone sequences and figures. Young children and adults both are able to learn the statistical structure of a language through statistical learning. It is, however, also very interesting and important to see whether multilinguals are better in discovering the statistical structure than bi- or monolinguals and that will be the aim of the present study. None of the experimental studies thus far have examined the relationship between statistical learning and multilingualism, but a few have looked at bilingualism and statistical learning. A study by Yim and Rudoy (2013), for example, focused on whether bilingual children would learn the statistical structure faster than monolingual children. We may hypothesise that bilingual children are advantaged when it comes to this, as they have been exposed to two languages from an early age on, which may be an advantage (Kovács and Mehler, 2009). This is also what Yim and Rudoy had hypothesised at first: “bilinguals' life experience with linguistic systematizing will influence their implicit statistical learning” (para. 29). Their participants were recruited thanks to flyers which were posted around the Northwestern Univeristy (para. 30) in the United States. The bilingual children in the study by Yim and Rudoy spoke Spanish at home and started learning English when they went to school at the age of three. The age of the monolingual children ranged from 5;1 to 13;2 (years; months), the age of the bilingual children ranged from 5;0 to 13;2 (years: months) (para.31). Both groups of children were exposed to a visual stream in which three base triplets were presented, just as in the study conducted by Abla and Okanoya (2009): when one figure appeared, the next figure would be
the one that follows in the triplet. Then, they were exposed to two sets of triplets: one base triplet and one false triplet. They had to press a button to indicate which of the two triplets they had seen before. The experiment consisted of 24 pair sets, there were thus 24 base triplets to identify. This was thus approximately the same experiment as the one by Abla and Okanoya (2009), except for the number of base triplets (there were only six base triplets in the study by Abla and Okanoya). Yim and Rudoy also did the same experiment with tone sequences, with the same participants as for the visual test. This experiment also consisted of three base triplets and false triplets. The participants were also asked to identify the 24 base triplets: they were asked to press a button if the triplet sounded familiar. In both experiments (visual and auditory), there was no statistically significant difference between the monolingual and the bilingual children. In other words, the monolingual children performed as well as the bilingual participants. This suggests that bilingual persons are not necessary better in seeing a statistical structure, even though one may think they are due to them being more familiar with multiple statistical structures. It might, however, also be that the difference between monolinguals and bilinguals is not large enough to lead to any statistical significant differences in performance. The present study will therefore use a very similar design as the studies mentioned above, but it will focus on a group of participants with a broader range in the number of languages they know.

The study conducted by Yim and Rudoy (2013) was not the only study that focused on bilingualism. Bartolotti, Marian, Schroeder and Shook (2011) investigated the influence of bilingualism and inhibitory control on statistical learning. The participants were divided into groups: low bilingual experience or high bilingual experience, and weak inhibitory control or strong inhibitory control (this was calculated with the Simon task). As the purpose of this present study is about multilingualism, in this section, we will focus only on the hypothesised difference between the two bilingual groups of the study by Bartolotti et al. (2011), and not on the difference between the two inhibitory groups. Two artificial languages were created, which were based on the International Morse Code alphabet, so that this would not look like any known language. Tones would be the basis of the six ‘letters’, and with these letters, words were created: three words for each of the two languages, words were composed of two letters. The letters were separated by a 300 ms pause. Within words, the transitional probability equalled 1.0, or 100 percent. Between words, the transitional probability was 0.5 (or 50%). The participants were exposed to the stream of tones for 4 minutes and 12 seconds, three times. After this, the participant had to choose between two Morse Code words: they had to press a button indicating which of the two words they already heard before. It was found that the high bilingual group “performed significantly better than chance” (p.5) while the low bilingual group did not. This means that the high bilingual group was able to learn the language, while the low bilingual group was not.
Another example of bilingualism having a positive influence on statistical learning is given by Wang and Saffran (2014): they tested this with a tonal language (when the meaning of a word differs depending on the pronunciation). This was done with an artificial language consisting of both syllables and tones, the participants were thus able to distinguish the syllables, the tones, or both of them (as is done in a tonal language). The participants were monolingual Mandarin, monolingual English or bilingual Mandarin-English speakers. The participants were exposed to the words of the artificial language in the familiarisation phase, during nine minutes. The transitional probability within words was 1.0 (or 100 percent), between words, it was 0.5 (or 50 percent). During the testing phase, they were exposed to one of the words of the previous phase, and one new, non-word. First, it was found that “bilingual Mandarin-English speakers outperformed their Mandarin monolingual peers, as well as the English monolinguals” (p.6). They also found that “bilingualism alone does facilitate statistical learning in this task” (p.6). This study thus suggests that bilingualism may also have an influence on statistical learning of a tonal language.

It seems thus that there are conflicting results when it comes to multilingualism and statistical learning. We may wonder why there is such a difference in results. The studies which show that bilinguals are better at seeing the statistical structure of a language (Bartolotti et al., 2011; Wang and Saffran, 2014) both have auditory stimuli, but this does not seem to be the main cause of the conflicting results, as Yim and Rudoy (2013) had both visual and auditory tasks. Furthermore, the procedure of the studies were quite similar: the participants were all exposed to a task which involved statistical learning and were tested afterwards. However, there was a difference in participants: Yim and Rudoy (2013) studied bilingual children, whereas Bartolotti et al. (2011) and Wang and Saffran (2014) tested students. We may thus wonder which circumstances make it easier to learn the statistical structure of a language.

2.5 Present study

The results of the study by Yim and Rudoy (2013) are not considered to be a predictive factor of the results of the present study, as there were other studies which proved different results. Wang and Saffran (2014) studied the effect of bilingualism in statistical learning of a tonal language. They found that “bilingual experience did enhance learning outcomes”. The study by Bartolotti et al. (2011) also suggests that bilingual experience enables to extract novel words from a continuous speech. Thus, we cannot say that the study by Yim and Rudoy (2013) is already a prediction of the present study. Furthermore, whereas Yim and Rudoy focused on the difference between monolingual and bilingual children, this study will focus on multilingual students. This means that, instead of looking at speaking one language versus speaking two languages, this study will look at the relationship between knowing multiple languages and the ease of learning statistical structures. As far as the researcher knows, this has not been done before: although the influence of
bilingualism on statistical learning has been the focus in previous studies, these were between a group of bilinguals versus monolinguals and looked at which group performed better. In the present study, the emphasis will lay on the relationship between the number of languages and the ability of discovering patterns. It is thus different from other studies and it aims at discovering more about statistical learning and multilingualism.

2.6. Expectations

Before testing the participants, it was expected that the multilingual people are better in seeing the statistical structure of the language. As they are more used to dealing with languages, it was expected that those who know multiple languages would be more experienced in discovering the hidden structure of a language. We have seen before that being exposed to two different languages may be an advantage when it comes to statistical learning (Bartolotti et al., 2011; Wang and Saffran, 2014). As seen before, Ellis et al. (2013) suggested that practice makes the memory stronger. In short, practice and experience are the main reasons why it was expected that the multilingual people will be better in seeing patterns. Furthermore, according to Bogaards (2001, as cited in Bartolotti et al., 2011), “successful acquisition of word forms […] increases the rate at which vocabulary is expanded” (p.6). Therefore, we may think that, if knowing multiple languages increases the ability of seeing a statistical structure, this may also have an influence on the reaction time of the participants.

We have seen in this chapter what the statistical structure of language is and what statistical learning can do when someone is learning a new language. As young as eight months old babies are able to differentiate words from non-words when making use of statistical learning. This is not only true for linguistic stimuli, but also for visual ones. In this study, statistical learning is used in order to investigate whether knowing multiple languages increases the chance of being able to see structure more rapidly. In the next chapter, we will explain how the experiment was carried out.
3. Methodology

In order to answer the question whether there is a relationship between being able to see patterns in a statistical learning task and the number of languages one knows, a research was done among multilingual students of the University of Groningen and the Hanze University of Applied Sciences. The research was inspired on the study by Abla and Okanoya (2009), in which participants were tested to discover whether they see regularities in visual stream. However, in these previous studies, the participants were not necessarily multilingual. In the present study, participants with varying linguistic backgrounds were tested.

In consultation, the test was taken from Liza Mossing Holsteijn's Master thesis (2016) in which she tested dyslexic vocational students. She investigated the influence of intentional learning on the learning outcome of a statistical learning task in individuals with dyslexia. Mossing Holsteijn used two tests in her study: a test in which intentional statistical learning was being assessed and a test in which incidental statistical learning was assessed. In this study, the test was not used in the same way, as this research was neither about the difference between intentional or incidental learning, nor about individuals with dyslexia. In the present research, only the incidental statistical learning test was used, as the participants did not ought to know on what they were tested. If they would have known, it may have influenced their results as they would have paid more attention during the familiarisation phase.

3.1. Participants

The participants in this study were Dutch and international students of the University of Groningen and the Hanze University of Applied Sciences in Groningen, the Netherlands. The sample consists of 31 students. All of the participants were between 19 and 30 years old; the mean age was 21.94 and the standard deviation was 1.79. Almost all of the participants were multilingual, however, some knew more languages than others (some of the participants knew two language whereas others spoke six). This design allowed to examine whether there was a difference in seeing regularities in a language when a person knows more languages.

When answering the questions of the questionnaire, most of the participants asked when they could indicate that they spoke a language, in other words, when they were proficient enough to be able to say that they know a language. As seen before, this is a difficult and complicated issue. With Grosjean’s (1989) definition in mind, the researcher gave the same answer to everyone who asked this question: when you consider yourself proficient enough to have an everyday life discussion in that language, you may indicate that you know this language.
There were 31 participants in this research, of which almost all considered themselves to be multilingual. There were three exceptions to this: one person who only knew how to read a second language, one who did not know a second language and one who considers being multilingual when one has learned another language from an early age onwards (younger than three).

Twelve men and nineteen women participated in this study. The youngest participant was 19 years old, the oldest 28. The participants came from different countries, as it was not required to be Dutch in order to participate in this study.

The names of the participants were asked at the end of the experiment, but these will not be used in this thesis, as it will be completely anonymous. The names were only asked in order to facilitate the overview of the participants for the researcher.

3.2. Materials and procedure

The research consisted of two parts: a test and a questionnaire at the end. The participants were first exposed to the figures in a familiarisation phase of two and a half minutes. When they had seen the continuous stream of figures, they were tested on the newly acquired information in a test phase, which will be explained in the next section. The questionnaire aimed at getting to know the participants' sociolinguistic background: how many languages they knew, where they were from etc. In the next paragraphs, the test will be explained in more detail. Afterwards, some more detailed information about the questionnaire will be given to clarify some of the researcher's choices.

3.2.1. Test

The test was made in E-prime 2 Professional, by Liza Mossing Holsteijn (2016). The test aims at discovering whether multilingual people see the statistical structure better (if they had more correct answers) and whether their reaction time was faster (if they needed less time) than those who know less languages. They were expected to learn the structure in the first phase and to apply this new knowledge in the test phase afterwards.

In this section, the procedure of the test will be explained in detail.

**Stimuli:**

The nonverbal statistical learning task consisted of six shapes: a square, a cross, a circle, a diamond, a triangle, and a octagon, which we can see in figure 1. The shapes have been combined in order to create three familiar pairs, which the participants saw during the familiarisation phase:
– a square and a pentagon
– a cross and a triangle
– a circle and a diamond

Figure 1: Figures used in the experiment, ranked according to the pairs

These familiar pairs are called base pairs. The shapes were presented in a continuous stream, one at the time. Each shape was presented for 800 ms, with an interstimulus interval of 200 ms. There was no information about the pairs in this phase, only the transitional probabilities will indicate the existence of the base pairs: 1.00 within pairs and 0.33 between pairs. This is the same as in Saffran et al. (1996): it is more probable that a square is followed by a pentagon than that a square is followed by a cross.

There will also be false pairs, which did not occur in the familiarisation phase. The false pairs are the same as the none-words in Saffran et al. (1996). The false pairs in this study were:
– a square and a cross
– a pentagon and a diamond
– a circle and a triangle

These shapes will not precede one another in this continuous stream, as only base pairs will be shown in the familiarisation phase.

During the familiarisation phase, each base pair was shown 24 times, which means that the participants were exposed to 72 pairs and a total of 144 individual shapes. This phase was done in order for the participants to discover the pattern and so that they would be able to differentiate the base pairs from the false ones.
This mirrors the test that was done by Saffran et al. 1999, the base pairs being words in their research and the false pairs being non-words. The participants had to differentiate the two in the test. The base pairs represent words in this task. In a continuous stream, words were 'hidden' without a clear marker where the word began and where it stopped. This is the same in this present study. The aim of the experiment is that people discover the beginning and the ending of a word (or in this case, a pair of figures) due to the statistical structure, even if they have never seen it before the familiarisation phase.

**Procedure:**
The participants were tested on a computer, individually. The researcher was present during the test. The participants were asked to take place in front of the computer, on which they were first welcomed and thanked by a text with the explanations of the test. The explanations on the screen were written in English. The researcher also welcomed and thanked the participants and gave some information (where they should sit, that the experiment takes about ten minutes and that a questionnaire will follow afterwards). This was either in English or in Dutch, whatever the participant was most comfortable with. The participants were able to ask questions to the researcher, but no information about the content or about the aim of the test was given, not even if they asked it. The participant did not know beforehand what the research was about. Some of them asked the researcher, but they answered that this question could not be answered. When the experiment (the test and the questionnaire) were both completed, some of the participants asked what the aim of the test was. Only after they had finished everything, this question would be answered.

During the first phase, the participants were exposed to the so called 'familiarisation phase', in which the previously mentioned continuous stream was presented. The shapes were presented one at the time, for 800 ms and with an interstimulus interval of 200 ms. In this phase, the base pairs were presented, however, the participant did not know this. They did not know why they were exposed to this continuous stream and what they had to do after it finished. The only clue for knowing what the base pairs were, were the transitional probabilities: as mentioned before, the transitional probability within pairs was 1.00 and 0.33 between pairs.

When the participants had been able to familiarise with the shapes (and unconsciously also with the base pairs), they went through to the test phase. In this test, the participants were exposed to 72 trials, so each pair was be shown twelve times. In each of the trials, two figures were shown separately, which formed a pair. This was either one of the three base pairs or one of the three false pairs. The base pairs have been shown to the participants during the familiarisation phase and the false pairs were unknown to them, although they were made up of the same figures as the base pairs. The shapes were presented with the same duration as during the familiarisation phase: 800 ms, with an interstimulus interval of 200 ms. When the shapes had been presented, the participants were asked whether they had seen this pair during the
familiarisation phase or not. If they had, they had to press the 'z'. If they had not seen this combination before, the participant had to press the 'm'.

3.2.2. Questionnaire

After the test, the participants were asked to fill in a questionnaire. It was done online, with the help of Google Forms. The participants were asked questions about their linguistic background, whether they were raised multilingual, how they learned their languages etc. There were different sections: the first section was about the participant's mother tongue. At the end of the section, the participant was asked if they were more or less proficient in another language. If so, they would be directed to the second section, in which they would find approximately the same questions: which language, how did they learn it, when did they learn it, with whom do they speak the language and how proficient they are in this language etc. This was repeated until they answered the questions for all of their languages. From language two on, the questions were the same for each language (in fact, only the questions for the mother tongue were slightly different). If they indicated that they were not proficient in another language, they would jump ahead to the last section, in which they had to fill in some personal information about themselves. In total, there were seven language sections, as it was not expected that any of the participants would know more than seven. The questions “do you have any trouble with reading or listening?” and “do you have any language disorder/difficulty with learning a language?” were aimed at getting to know whether an affection concerning learning a language could influence the participant’s score. If a participant would have answered “yes” and it was thought that this might have influenced their score, the result would not have been taken into account.

The reason why the questionnaire was done after the test and not before, is because participants may have guessed what the research was about if they would have filled in the questionnaire before the test. This may have influenced the data, as they may have tried to remember the base pairs in the familiarisation phase.

The questionnaire is included in Appendix I of this study.
3.3. Analysis of the data

The data was analysed using SPSS Statistics 23 program. All participants were given a number from one to 31, so that their anonymity would be guaranteed. The scores of the participants were the means of their correct results in each trial. Furthermore, besides the accuracy, the reaction time of the participants was also be analysed. It is important to do so, as the aim of this study is not only to discover if multilingual people are better at seeing a pattern than monolinguals, but also if they are quicker in seeing it. A correlation test should give more information about the effect the number of languages has on how well the participants performed in this study. Furthermore, the differences between groups were mostly analysed using a Mann-Whitney U test.
4. Results

In this section, the results of the experiment mentioned in the previous section will be described. As the experiment was completely anonymous, no names or other information that might reveal the identity of the participants will be mentioned. Instead of names, numbers will be used if a specific participant has to be mentioned for any reason whatsoever.

In this section, the participants will be described and afterwards, the results of the various analyses will be given. First of all, the results of the relationship between knowing multiple languages and the ability of seeing patterns. Then, the reaction time and the relation with the scores and languages will be analysed. Lastly, the other factors (early and late learners, naturally acquired and learned at school, the relationship between daily used language and the accuracy scores, the feeling of being a multilingual person and the ease of acquiring a new language) will be analysed.

The meaning of these results will not yet be explained in this chapter, but in chapter 5 (“Discussion”).

4.1. Representation of the participants

In this part, a description of the participants will be given, in order to draw an image of those who participated in this research.

4.1.1. Distribution of the languages

On the one hand, it was not easy to find enough people who knew only one language, but on the other hand, it was also very difficult to find people who knew five or six languages. Therefore, the different groups were not perfectly balanced, as can be seen in figure 2. Most of the participants spoke two (eight participants), three (eleven participants) or four (eight participants) languages.
Although the groups were not equally distributed, it is a good representation of real life: there are not so many monolinguals in the Western world, but speaking six languages is also not very common.

Furthermore, in the Netherlands and many other European countries, a second and third language are compulsory in secondary school, so that may also be a reason why there were so many participants who are able to speak two, three or even four languages. We can see this in the distribution of which languages are spoken by the participants. As we can see in figure 3, English is spoken by everyone in this research, which is not surprising, as the experiment was in English and therefore, it was required for the participants to speak this language. The second most spoken language was Dutch, which is also not surprising, as the experiment was done in Groningen, in the Netherlands. Not all the participants spoke Dutch, as there were also some international students of the university and it was not required to speak Dutch. The amount of German and French speakers can be explained by the fact that a second and third language are compulsory at secondary school, and people in the Netherlands often opt for German or French as their third language (Rijksoverheid 2014b). In the second part of secondary school, pupils may even choose another language (Rijksoverheid 2014a). Frisian was not spoken by many participants, as only four said they were able to speak it, and only one participant considered this language as their mother tongue. This is remarkable, because there were several participants coming from Friesland. Furthermore, they should all have had Frisian at school, as this is a compulsory subject at almost all primary schools in Friesland (Rijksoverheid, 2014).

Participants spoke the other languages for various reasons: as their mother tongue (international students), due to their studies, because they lived in that country for a while, because of friends...
4.1.2. How did the participants learn their languages?

It may be interesting to see how the participants have acquired their languages, as there may be a difference between the scores depending on how one learned their languages: if they were raised in this language, if they wanted to learn the language, or whether they were ‘forced’ to learn it in school. As can be seen in figure 4, 19 out of 31 participants learned (the majority of) their other languages at school. This may again be explained by the fact that it is compulsory to learn a second or third language at school, and not only in the Netherlands. According to Eurostat, for most European children, it is compulsory to learn at least one foreign language. Furthermore, the Barcelona European Council of 2002 recommended that children had to be taught at least two foreign languages from an early age on (Eurostat, 2016). This applies to most of the participants, as 24 out of 31 participants came from one of the countries of the European Union, and one from a candidate country.

One participant was not multilingual. The other eleven participants acquired their languages naturally. Naturally acquired meant that it was not learned at school or in any other form of a classroom setting. Naturally acquired includes being raised bi- or multilingual, learning a language due to living abroad, through friends or a partner, playing video games, watching foreign television, self-study...
Figure 4: Distribution of naturally learned languages versus learned at school

As the greatest part of the participants learned their languages at school, we may think that the age at which the participants learned their languages is rather high. In fact, figure 5 shows that people seem to acquire a second language rather earlier, but the more languages, the later they have learned it. Only two out of ten participants stated that they learned their fourth languages between the age of three and ten. One person was excluded in this graph, as they claimed to speak three languages as their mother tongue. As it was not clear at what age they acquired all of their languages, it was thought best to remove the data for this graph.

Figure 5: Number of participants and age of acquisition of their languages
4.1.3. How often do the participants use their languages?

Almost all of the participants were multilingual (i.e. spoke multiple languages, it does not mean they considered themselves as multilingual), but that does not mean they use all of their languages equally often. The greatest part of the participants stated that they spoke three languages (eleven participants), but as we can see in figure 6, only four participants actually used three languages on a daily basis. Four people used only one language on daily basis and as can be seen on the graph, the majority uses two languages on a daily basis.

![Languages used on daily basis](image)

*Figure 6: Languages participants used on a daily basis*

This distribution will not be used in the main analysis of this study, the correlation between the number of languages and the accuracy scores, as it was not required for the participants to use multiple languages on a daily basis. However, it will be interesting to see if people score better if they use multiple languages on a daily basis, therefore, this will also be analysed.

To go further into detail, figure 7 shows how often each language is used on a daily basis. The numbers correspond to how many times the participants indicated to use that language in each situation. For example, 17 times, a participant stated to use Dutch at home on a daily basis. There were several languages that were spoken by only one person; a category ‘other’ was thus created for these languages.
A comparison can be made between daily use and when a language is never used. Figure 8 represents the situations in which the participants stated they never use a language. As can be seen in figure 8, there is a broader distribution when it comes to the non-use of the languages. Dutch seems to be used most often, whereas English is neither used very much at home nor with relatives. The fact that the participants answered ‘never’ so many times when it comes to speaking the language with their partner may be due to the fact that there was no ‘not applicable’ option.

In figure 7, Polish was included in the category ‘other’ whereas it is mentioned in figure 8 as a category. This is because no Polish speaker stated that they use Polish on a daily basis. The Polish speakers have declared that, in some situations, they never use the language. Therefore, Polish is mentioned in figure 8.
4.2. The relationship between knowing multiple languages and the ability of learning a new one

4.2.1. Descriptive statistics

After having tested the participants, their mean accuracy score was calculated: on each trial, the participant got a 0 (when they were wrong) or a 1 (when they were right). All these scores were added together and divided by the number of trials (72), so that the mean score could be used for the analyses.

There were 31 participants, and the mean accuracy score was 0.59 (this was based on all the accuracy scores divided by 31 participants). As the maximum score was 1, we can say that the mean score is a little above chance level (0.5), as if they have guessed everything, there is a fifty percent chance they guessed it right. The maximum score was 0.96 and the minimum 0.32: this will be the focus of the next section. The range was 0.64 and the standard deviation was 0.17, which does not show a great difference between the participants.

Table 1 shows the descriptive statistics of the accuracy per language. For “one language” and “six languages”, some data are not available due to the fact that there was only one participant in the group. We may notice the mean score per language: the scores do not seem to be differ very much between the different language groups.
### Table 1: Descriptive statistics per language (accuracy scores)

<table>
<thead>
<tr>
<th>Number of languages</th>
<th>Mean Accuracy</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5278</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.5388</td>
<td>0.78</td>
<td>0.32</td>
<td>0.46</td>
<td>0.17207</td>
</tr>
<tr>
<td>3</td>
<td>0.6831</td>
<td>0.96</td>
<td>0.44</td>
<td>0.51</td>
<td>0.18559</td>
</tr>
<tr>
<td>4</td>
<td>0.5729</td>
<td>0.89</td>
<td>0.44</td>
<td>0.44</td>
<td>0.14159</td>
</tr>
<tr>
<td>5</td>
<td>0.4028</td>
<td>0.46</td>
<td>0.35</td>
<td>0.11</td>
<td>0.07857</td>
</tr>
<tr>
<td>6</td>
<td>0.4722</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.2.2. Correlational analyses

In order to know whether or not there was a correlation between the number of languages someone knows and their ability to recognise a pattern, a Spearman correlation was done. This analysis was performed with the same mean accuracy score as described above and the number of languages someone knows. All participants were included, there was no reason to exclude some of the data.

As can be seen in figure 9, there was no linear relationship between the variables. On top of this, the data was not normally distributed. This is why the Spearman correlation was used for this analysis instead of a Pearson correlation.

![Figure 9: Scatterplot of the relationship between accuracy and number of languages](image-url)
The Spearman correlation showed that there was no correlation between the number of languages someone knows and their ability of seeing patterns in a nonverbal statistical learning task, $r_s = -.103$, $p = .581$. This can also be noticed in the scatterplot, as for all the languages, the accuracy scores are very widespread. There seems to be a huge difference between the best and the worst score for each language.

### 4.2.3. Z-scores

The z-scores were calculated with SPSS for the accuracy scores of the participants. This was done instead of a one-sample t-test, as the standard deviation was known and this experiment had more than thirty participants. The z-scores show how many standard deviations the participant is away from the overall mean score. In this way, we can see who scored above the mean and who scored below. In this case, it is interesting to see which participants scored above the mean: did those who knew more languages score more frequently above the mean than those who knew less languages? The results are presented in table 2.

<table>
<thead>
<tr>
<th>Languages</th>
<th>Number of Participants</th>
<th>Above Mean</th>
<th>Below Mean</th>
<th>Percentage above mean</th>
<th>Percentage below mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>38%</td>
<td>63%</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>64%</td>
<td>36%</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>38%</td>
<td>63%</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Table 2: Scores above and below the mean, according to the z-scores*

We can thus see that, on average, those who knew three languages scored more above the mean than any other language: 64% of those who knew three languages scored above the mean, according to the z-scores. This is relatively high if compared to those who know two or four languages: in both cases, 38% scored above the mean. In the case of knowing only one, five or six languages, it is more difficult to draw a conclusion, as in each case, this was based on only one or two people.
4.3 Highest and lowest score: a representation of these participants

To provide a more detailed view of the findings, it was decided to take a more qualitative look at the data and see what the differences are between the participant who had the highest accuracy score and the one who had the lowest: how far are their scores from one another, how many languages do they know and what other differences can be found?

The highest

The best participant scored 0.96 on a maximum score of 1. This means that this person got almost everything right. The participant knew three languages (Dutch, English and Spanish), of which they knew two before the age of three and one after the age of thirteen. The mother tongue of this participant was Dutch. Dutch and English were known at a good level, but Spanish on an average one. They consider themselves to be multilingual, but would not say they learn languages with ease (only after putting some effort in it). They used two languages on a daily basis (Dutch and English). They have learned the languages at school. Furthermore, they study at the University of Groningen. This participant was female.

The lowest

The participant with the lowest score, scored 0.32 on a maximum score of 1. This means that approximately, they were right once every three times. The participant initially stated that they knew four languages: English, Dutch, Frisian and German, but when they had to state their proficiency in each language, this participant stopped after Dutch and English. Therefore, in the analysis, this participant was considered to know two languages instead of four. Dutch was the mother tongue of this participant and they knew English at a relatively good level. English was learned between the ages of three and ten. They considered themselves to be multilingual, but stated that they do not learn languages with ease and that they have a “lack of talent”. They use both languages on a daily basis and they have learned the languages naturally. They study at the Hanze University of Applied Sciences. The participant was male.

If we look at the results of the participants with the highest and the lowest score and the mean scores described in table 1, the following may be noted: the best participant knew three languages, which seemed to be the best group when it came to accuracy scores (with a mean of 0.69). The participant with the lowest score knew only two, this group had an average of 0.54. This two-language group does not have the lowest mean, although they do score under the overall mean.
4.4. Reaction time

The reaction time of the participants was recorded, in order to see if there was a correlation between the time needed and the number of languages that the participants knew. The score was calculated on the basis of all reaction times of each trial. Before analysing if there was such a correlation, the descriptive statistics will be presented.

As for the accuracy scores, there were also 31 participants, with a mean of 662.55 ms. The maximum was 1425.69 ms and the minimum 291.86 ms. The standard deviation was 243.04 and the range was 1133.83.

As we can see in table 3, there were some differences between the languages groups, but there does not seem to be huge differences if we look at the overall standard deviation. Some data was not available, because in some groups, there was only one participant.

<table>
<thead>
<tr>
<th>Number of languages</th>
<th>Mean Reaction time (ms)</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>765.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>594.28</td>
<td>856.97</td>
<td>336.07</td>
<td>520.9</td>
<td>195.23</td>
</tr>
<tr>
<td>3</td>
<td>661.94</td>
<td>1425.70</td>
<td>291.86</td>
<td>1133.83</td>
<td>325.32</td>
</tr>
<tr>
<td>4</td>
<td>720.21</td>
<td>1064.07</td>
<td>323.46</td>
<td>740.61</td>
<td>226.15</td>
</tr>
<tr>
<td>5</td>
<td>688.22</td>
<td>756.40</td>
<td>620.04</td>
<td>136.36</td>
<td>96.42</td>
</tr>
<tr>
<td>6</td>
<td>600.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Descriptive statistics of per language (reaction time)

A Spearman correlation was done in order to analyse whether or not there was a correlation between the number of languages a person knew and the reaction time. The same problem as in the previous section occurred, there was no linear relationship between the variables (as can be seen in figure 10), therefore, a Spearman correlation was thought to be the best option.
The Spearman correlation showed that there was no correlation between the number of languages someone knows and their reaction time in this experiment, $r_s = -.149, p = .425$.

In order to analyse the reaction time in further detail, a multiple regression was performed. In this way, it would become clear if the accuracy score or the number of languages someone knew could influence the reaction time: it might be thought that, if someone knew the structure (i.e. accuracy), they might have answered quicker. On top of that, if they knew more languages, they might have reacted faster due to their experience in shifting between languages.

Thus, a multiple regression was done to predict reaction time from the accuracy scores of the participants and the number of languages they knew. These variables did not statistically significantly predict the reaction time, $F(2, 28) = 0.114, p > .05, R^2 = .008$. Nor accuracy scores added statistically significantly to the prediction, $p = 0.999$, neither did the number of languages spoken by the participants, $p = 0.640$. 

Figure 10: Scatterplot of the number of languages and the reaction time

![Scatterplot of the number of languages and the reaction time](image-url)
4.5. Other factors

Now that we have seen that there is no correlation between the number of languages a person knows and statistical learning, but that there appears to be a slight advantage for people who know three languages, it may be interesting to look at the other factors of language learning which were explained during the representation of the participants. It may give is a clue which of these factors may influence the ability of learning through statistical learning.

4.5.1. Early and late learners

As discussed in 4.2.2., the participants learned their languages at different ages. What does this mean for their results on the test?

Three groups were made: early learners (younger than three years old), middle learners (between the ages of three and ten) and late learners (older than ten). This division was based on their second language, as these was the first language they acquired after their mother tongue. The reason why there was a middle group is because there were many participants who stated that they learned their second language between the ages of three and ten. As the exact age at which they acquired their second language was not known, it was difficult to divide them into two groups (early and late).

Figure 11 shows the scores of the early, middle and late learners.

![Score: when did you start learning other languages?](image)

*Figure 11: Mean accuracy scores of early, middle and late learners*

A Kruskall Wallis H test showed that there was no significant difference between the accuracy scores of the early, middle and late learners, $\chi^2(2) = 3.777$, $p = 0.151$, with a mean rank of 19.88 for early learners, 15.23
for middle learners and 11.07 for late learners. Therefore, in this test, there was no difference in scores between the ages at which the participants acquired their second languages, although the mean score of the early language learners was a bit more higher than those of the other two groups. No post hoc test was done to determine where the differences lay between the group, as the Kruskall Wallis H test did not show a significant difference.

4.5.2. Naturally learned or at school

It was already discussed before that the participants learned their languages in all kinds of ways: at school or at home, when playing video games, watching television, self-study... It may be wondered whether those who learned it naturally are better in learning statistical structures because of the different exposure to the language: on the one hand, they may be more motivated to learn the language, because they were not ‘forced’ to do it. On the other hand, at school, there is more focus on grammar and syntax, which may be more helpful to see the structure.

In figure 12, the difference between the mean scores of the naturally language learners and those of the learners at school are being showed.

![Score: how did you learn your languages?](image)

Figure 12: Mean score of naturally language learners versus learners at school

According to a Mann-Whitney U test, there was no significant difference between those who learned their languages naturally (Mean rank 13.91) and those who learned it at school (Mean rank 16.42) (U=87.5, p = 0.463). Although those who learned most of their languages at school show some on average better results, the difference is not enough to say that they were significantly better.
4.5.3. Considered multilingual

Being multilingual according to the definition given at the beginning of this research does not mean that everyone feels multilingual. Out of 31 participants, five did not consider themselves multilingual, although almost all were multilingual according to the definition. One of them spoke only one language (therefore, they were not multilingual), three spoke two languages and one even spoke three languages. One of them complemented that they considered someone to be multilingual when “you start learning both languages from a very early age (< 3 years)”. The remaining 26 participants all considered themselves to be multilingual (or bilingual).

The mean accuracy scores were analysed, as it might show a difference. If one feels multilingual, maybe they will more motivated to look for a structure. In figure 13, the mean accuracy scores are being shown. There seems to be just a very small difference between the scores of the two groups.

![Score: do you consider yourself multilingual?](image)

*Figure 13: Difference between those who consider themselves multilingual and those who do not*

According to a Mann-Whitney U test, there was no significant difference between those who considered themselves multilingual (Mean rank 16.19) and those who do not (Mean rank 15) (U=60, p = 0.788).
4.5.4. Trouble with learning new languages

Comparing those who learn language with ease and those who undergo some trouble when learning a new language may be interesting. It is not a strange thing to think that it is easier to learn a new language when one actually is good in it. That is what the researcher wanted to test: are those who claim to be better in learning languages also better in statistical learning?

For this analysis, three groups were made: yes, average and no. The average group included everyone who answered “average”, “moderate”, “yes and no”, “only when forced through school” etc. The difference between these groups can be seen in figure 14. The first thing to notice is that those who answered that they learn languages with ease have scored a little bit lower than those who do not claim to have some trouble with learning languages. The second group (average) was not taken into consideration in this analysis, because it was thought to be the most interesting to compare only the ‘extremes’ of these answers.

According to a Mann-Whitney U test, there was no significant difference between the participants who learn languages with ease (mean rank 10.47) and those who do not (mean rank 12.33) (U=37, p = 0.532).
4.5.5. *Number of languages used on a daily basis*

It has already been stated in 4.2.3. that knowing a certain number of languages does not mean that the participants actually use all of them on a daily basis. In fact, eight participants stated they knew four languages, but as can be noted in figure 6, only one of them actually used four languages on a daily basis. Using multiple languages daily may mean that the participants actually uses them more often and therefore are more trained in this, it may be interesting to see what kind of an effect this may have on their accuracy scores: does using multiple languages daily enhances the ability of seeing a statistical structure?

![Figure 15: Scatterplot of the languages used on a daily basis and the accuracy scores](image)

A Spearman correlation was done in order to investigate if there was a correlation between the languages used on a daily basis and the accuracy scores of the participants. Figure 15 shows the scatterplot.

The Spearman correlation showed that there was no correlation between the number of languages someone used on a daily basis and seeing patterns in a nonverbal statistical learning task, $r_s = -.143$, $p$
Just as in the Spearman correlation between all the languages a person knows and the accuracy scores, there was no correlation between languages used on a daily basis and the accuracy scores.

### 4.4.6. Gender

The last factor that is interesting to look at, is gender. Is there a difference between the accuracy scores of the female and male participants? There were nineteen women and twelve men.

In figure 16, it may be noted that the female participants scored higher than the male participants. On average, the women scored 0.63. The average score for men was 0.52.

![Score: Gender](image)

*Figure 16: Difference between scores based on gender*

According to a Mann-Whitney U test, the women (mean rank 18.79) had a significantly higher accuracy score than the men (11.58) (U=61, p = 0.031).
5. Discussion

The aim of this study was to discover whether it was easier for people who know more languages to discover a hidden structure in an artificial, nonverbal statistical learning task. This was executed with an experiment made in E-prime. A visual statistical learning task was created, in which the probability of one figure following the next was higher when they formed a base pair. Furthermore, it was also looked at whether those who knew more languages were also faster in seeing this structure. Lastly, this study looked at the other factors that may have influenced the participants’ ability of seeing patterns.

Before the analyses, it was thought that those who knew more languages would also be better in seeing the statistical structure of this experiment. This was thought because of the studies by Bartolotti et al. (2011) and Wang and Saffran (2014). Bartolotti et al. (2011) found that the high bilingual group performed better than the low bilingual group. Wang and Saffran (2014) found that bilingualism “does facilitate statistical learning” (p.6). As it was thought that speaking multiple languages would enhance statistical learning, it was also thought that those who knew more languages needed less time to think about the right answer, thus that their reaction time would be lower than those who knew less languages (Bogaards, 2001, as cited in Bartolotti et al., 2011). As became clear after the analyses, this was not particularly the case for both hypotheses.

5.1. Number of languages and accuracy scores

As was shown in chapter 4, a difference between accuracy scores could be noted between the different language groups: especially those who know three languages seemed to be better than the other groups. This can be seen both in the mean score per group (0.68 whereas the overall mean was 0.59) and in the z-scores (64% of those who knew three languages scored above the mean). The participants who only knew one language scored below the mean, but interestingly, the participants who knew five or six languages (three participants in total) also scored below the mean.

This goes against the expectations prior to the study, as it was the group with the most average number of languages (three languages) that scored the highest. Furthermore, it was surprising to find that those who knew five or six languages all scored below the mean, as it was expected that the more language you know the better you are at extracting a hidden structure. Those who knew four languages had the same relative number of participants scoring above the mean than those who knew only two languages. As bilingualism may influence the ability of learning a statistical structure (Bartolotti et al., 2011; Wang and Saffran, 2014), it was thought that those who knew one or two languages would have a lower score than the participants who knew multiple languages. The participants who knew one or two languages indeed scored rather average (0.53 and 0.54 respectively). It was not expected, however, that those who knew five (with a mean
of 0.40) or six languages (with a mean of 0.47) would have a score lower than the overall mean (0.59). As the maximum score was 1, we can say that those who knew one, two or six languages were at chance level (0.5). Those who knew five languages were a little below chance level. We cannot say that those who knew multiple languages were better at statistical learning in this visual, nonverbal statistical learning task. It was thought that when someone is relatively good at noticing patterns, they would also be relatively good at discovering the statistical structure of a language or vice versa. However, as the results of this study show that those who knew more languages were not better at noticing patterns, we also cannot imply that they are better in seeing the structure of a language.

The results clearly do not match the expectations. It is thus not surprising that there was no correlation found between the number of languages a person knows and the ability of learning patterns. However, this does not mean that people who know more languages are not advantaged when it comes to statistical learning. There may be several reasons why there did not seem to be a correlation. Maybe the participants often overrated themselves, so they may have said that they spoke more languages than they actually did. We have seen that most of the participants did not use all of their languages on a daily basis. It may be the case that they are not proficient enough to be considered as multilingual. On the other hand, there was also no correlation found between the number of languages a person uses on a daily basis and the ability of learning patterns, but this will be discussed in more detail later on (in section 5.3). It may also be the case that these participants had some difficulties with implicit statistical learning. As one of the participants said after the test and after having heard what the test was about: “If I had known what it was about, I would have represented the multilinguals better.”

Another important point is that the participants in this study were not all raised multilingual, so we may wonder if they will be as good as those who were. Nonetheless, it might be possible that those who did know multiple languages from early childhood were better in seeing the statistical structure than those who knew less languages or who learned their languages at a later age, as the younger learners probably have encountered structures more often (as they are more experienced with different structures of languages). This may imply that they have seen it more often.

Although we cannot say that there is a correlation between the number of languages a person knows and the ability of seeing patterns in a nonverbal statistical learning task, an interesting result was found nonetheless. The results of the means scores and the z-scores showed that those who know three languages performed better than any other language group. We can see this in several results. First of all, the participant with the highest score knew three languages. Furthermore, the mean score of those who knew three languages was 0.68, as opposed to 0.57 for the second best group (four languages). The better performance of the three-languages group can also be found in the z-scores: 64 percent of this group
scored above the mean, while in the case of those who knew two or four languages, 38 percent of each group scored above the mean.

It does thus seem that people who know three languages have an advantage over those knowing less or more. It was expected that knowing multiple languages would be an advantage (Bartolotti et al., 2011; Wang and Saffran, 2014), but not that those who knew five or six languages would have a lower score. We may hypothesise that knowing ‘too many’ languages could be a disadvantage when it comes to statistical learning, as it may be too much.

5.2. Reaction time

As stated above, it was expected that those who knew more languages would be better in seeing patterns. A logical expectation was that, if this was really the case, they would also be faster at responding, as we have already seen before: according to Bogaards (2001, as cited in Bartolotti et al., 2011), successful word acquisition contributes to the rate at which vocabulary is expanded (p.6). It was therefore thought that those who knew less languages would have to think longer about the correct answer, as they may be slower in seeing the structure.

However, a Spearman correlation showed that there was no significant correlation between the number of languages a person knows and the reaction times in this test. In order to go into further detail, a multiple regression was used, so that it could be found out if the number of languages, but also the accuracy score could have had an influence on the reaction time. The result of this analysis was also that it was not significant. Therefore, this analysis does not prove that people who know more languages are faster in recognising patterns. However, it does not mean that the number of languages does not influence the reaction time. As for the accuracy score, there may have been some other causes that may have influenced the scores. The same explanations for the results of the lack of a correlation between the accuracy scores and the number of languages (explained in 5.1.) may be applied to the reaction times. Further limitations of this present study will be discussed below, in section 5.4.

5.3. Other factors

In this study, it was also looked at if there were more factors that may influence the participants’ ability of recognising patterns after being exposed to it for 2.5 minutes. The accuracy scores were once again analysed with the following independent variables: the age of when the participants became bilingual, how they learned it, whether or not they consider themselves to be multilingual, how well they learn a new language, how many languages they speak on a daily basis and gender.
It was found that only one of these factors is in fact statistically significant: on average, the women tended to be more accurate than the men. According to Kaushanskaya, Marian and Yoo (2011), “women tend to outperform men on a range of linguistic tasks” (p.31), because women’s declarative memory system seems to be more efficient (p.31). Therefore, it did not come as a surprise that this was also the case in this present study.

Although a small difference between the groups can be found in figure 11, 12, 13 and 14, this was not enough to be considered statistically significant. This suggests that in this case, it did not make a difference when the participants learned their second language or how they learned it. It may also mean that people do not have to consider themselves to be multilingual or consider themselves to learn languages with ease for them to see the statistical structure of a language. It does also not prove that those who speak more languages on a daily basis are better in seeing patterns in such a task, as may have been expected. As not everyone uses all of their languages daily, it may be the case that someone who knows four languages uses as many languages on a daily basis as someone who knows only two. This means that one uses as many languages on a daily basis as the other, making them trained in both languages. However, this analysis did not prove that those who used more languages on a daily basis are also better in recognising the patterns in a nonverbal statistical learning task.

Another factor that could have influenced the score of the participants was the following: in the questionnaire, there were two questions which aimed at knowing whether the participant had any trouble with reading or listening and if they had a language disorder. However, this was not analysed as there were no participants whom had such serious problems that their data should be excluded. One participant suffered from concentration problems and mentioned they had a slow reading pace and heard less well in noisy areas. It was believed that this did not influence their score on this test, as it was completely quiet during the running of the test. Furthermore, their score was one of the highest, so it seemed that their concentration problems did not intervene during the test.

5.4. Limitations of the study

As in all studies, there were certain aspects that may be improved before doing further studies.

First of all, if this experiment were to be redone, the number of participants should be higher. More convincing conclusions can be drawn from a bigger number of participants. Thirty-one participants are not a very good representation of the whole population. For the same reason, it would be interesting to work with another age group or another level of education, as in this study, only students between the ages of 18 and 30 were tested. It would be interesting to have more diversity to see where a difference in ability of statistical learning can be found.
5.4.1. Circumstances of the test

Due to some problems, it was not possible to test all the participants under the same circumstances. Some of them were tested in the office of Ms. Loerts at the University of Groningen, while others were tested in the study rooms in the same building. It can be imagined that this was the source of all different kinds of circumstances for all of the participants: some of them were tested in a small room with only the researcher, while others were surrounded by a lot of other people (although in all cases, it was quiet in the room). Furthermore, some of the participants have made the test on a desktop, while others had to make it on a laptop. Although these are all small differences, it may be better to have the same circumstances for everyone. In this way, it can be assured that nothing other than the experimental properties has influenced participants.

5.4.2. The testing phase

The experiment made in E-prime was not made by the researcher themselves, but by Liza Mossing Holsteijn. Her experiment was in Dutch, and as this present study was made accessible for international students, it had to be translated into English. However, only after having tested about twenty out of 31 participants, it was noted that some of the text was still in Dutch. When the participant had to choose whether or not they had seen the figures in a particular order before, the words 'juist' and 'onjuist' were written on the screen, instead of 'right' and 'wrong'. However, it was stated in English which buttons they had to use during the explanation. Although none of the participants said anything about it, it might have been the case that the reaction time of some of the participants was influenced by this, especially for those who did not know Dutch. The scores of the international students were not excluded from the analyses, as the differences in reaction times were very small: for all the participants, the mean was 662.55 ms. For the Dutch participants, it was 676.73 ms and for the international participants, it was 645.34 ms. The standard deviation was 243.04. It was also not thought that it had influenced the mean score of the international participants. The mean score of all participants was, to be precise, 0.5875. The mean score of only the Dutch participants was 0.5866 and the one of the international participants was 0.5886. The differences between these scores were so small, that it was thought that the ‘right’ and ‘wrong’ being in Dutch did not have an influence on the accuracy scores of the participants.

Not only the test itself could use some improvements, but also the questionnaire the participants had to fill in afterwards. First of all, an improvement could be made for the following question: “How often and in what context do you use this language?” (for each language). The participant had to fill in how often they...
use each language at home, at school, at work, with friends, with relatives, with their partner, when watching television/radio and when reading books/newspapers. First of all, international students did not know what to answer at the 'at home' question, as they did not use their mother tongue very often during their temporary home (Groningen), but they use it when they are back in their home country. Furthermore, a 'not applicable' option may have been useful, as not everyone had a job or a partner. When this was the case, they answered 'never', but due to this, it was not known whether the participants who answered ‘never’ actually never used the language in this case, or that they did not have a job or partner.

Another point of improvement may have been to take into account that some of the participants may have multiple mother tongues. One participant had three mother tongues, so they answered the questions related to the mother tongue for all the languages at once. A consequence of this, is that there was no detailed information for each language. Another participant had two mother tongues, and chose to answer every question per language.

The last point of the questionnaire where some improvements are needed, were the open questions. When answering questions like “Would you call yourselves multilingual?” and “Would you say that you learn languages with ease? Why (not)?”, many participants tended to answer with “it depends” or “yes if ...., but no if....”, making it very difficult to make groups for the analysis.

Not only for the open questions, it was sometimes difficult to make groups for the analyses: for many analyses, the participants had to be divided into two or three groups. For example for the question who was better at statistical language learning, those who acquired their languages naturally or at school. Many participants acquired one or more languages naturally, but still learned one or more languages at school. They were divided in groups according to how most of their languages were acquired. For example, if a participant learned three languages naturally and one at school, they were placed in the 'naturally' group. This could have been a problem if a participant would have known four languages, of which they acquired two languages naturally and two at school. This was never the case in this study.

Lastly, it is important that each participant knows the definition of when one is able to say they know a language. Many participants asked whether they could answer they knew another language, as they did not know if they were proficient enough. If this is not known by each participant, it may be the case that they state they know less languages than they in fact do, or that they overrated themselves. This could also be solved with a standard proficiency test (for example a DIALANG test). This may ensure that the participants do not underrate or overrate themselves, and that we may be sure to have the right amount of languages per participant. This was not done in this experiment, because of the limited time.
5.5 Yim and Rudoy (2013)

In Chapter 2, we have seen that bilingual children were not better at learning the statistical structure of visual and auditory streams, according to Yim and Rudoy (2013). Although at the beginning of this present study, it was thought that this would not mean anything of importance for this study (as other studies like Bartolotti et al. (2011) and Wang and Saffran (2014) have stated that bilinguals may have an advantage) we have seen that there was no significant difference found in any of the analyses, except for gender. We might thus think that, just as in 2013, this present study does not prove that knowing multiple languages can be seen as an advantage when it comes to statistical learning. However, it seems that those who knew three languages performed better than any other group. We cannot say that, just as in Yim and Rudoy (2013), knowing multiple languages does not seem to have an influence on statistical learning; the positive influence of this may be limited to a certain number of languages. In order to know more about this, it would be interesting to redo the experiment.
6. Conclusion

Researchers have found that people often use statistical learning in order to recognise patterns. Young infants already do this when they are eight months old, according to Saffran et al. (1996). After being exposed to an artificial language for only two minutes, the children were able to recognise the words of the artificial language. Not only children, but also adults are able to do this. They can do this with speech (Saffran et al., 1996), tone sequences (Saffran et al., 1999) and visual stimuli (Fiser and Aslin, 2002, and Abla and Okanoya, 2009). They are able to do this because of the probability of one word following the other: some words are more likely to follow some words than others. This probability is called the “transitional probability”. These transitional probabilities are used in experiments in order to know how well people can learn the statistical structure of a language. Participants are exposed to a statistical learning task in which segments of words are more likely to follow one another within words than between words (1.00 within words and 0.33 between words). In languages, the transitional probabilities within words are also higher than the transitional probabilities of the accidental sound sequences between word boundaries.

This was replicated in this present study. The participants watched a continuous stream of figures in which pairs were hidden. The transitional probabilities within pairs was 1.00 and those between pairs was 0.33. After being exposed to the stimuli for two and a half minutes, they were asked whether or not they had seen the pair during the familiarisation phase. Their score was calculated on the basis of their correct answers. The highest possible score was 1, the lowest possible was 0. The best participant had a score of 0.96, the one with the lowest score had a score of 0.32. The rate at which they answered was also recorded, in order to know if some participants would be faster than others. After having completed the experiment, the participants were asked to fill in a questionnaire in order to get to know them a bit better. These answers were used for severable purposes: first of all, to draw an image of the participants, and secondly, they were used in order to answer the question of which other factors may have had an influence the score of the participants.

However, just as in Yim and Rudoy (2013), there was no proof that those who knew more languages were also better in learning patterns than those who knew less languages. There was no significant correlation found between the six language groups, despite the expectation that those who knew more languages would be more trained in seeing a structure. It was also thought that those who knew more languages would need less time to see the structure, because of this experience. As they were not necessarily better in seeing this, the expectation that they needed less time was also false: there was no significant correlation between the groups. In this study, we also looked at other factors. However, there was no proof that age, the way of learning a language, to be considered multilingual by oneself, how well they learn a new language or how many languages were used on a daily basis had any influence on the accuracy scores.
There were neither significant differences found between the groups, nor was there a correlation between accuracy scores and languages used on a daily basis. Only a significant difference between gender could be found in this study: women had higher accuracy scores than men did. This is a general tendency in these kind of studies: women tend to perform better than the male participants (Kaushanskaya et al., 2011). Although none of the analyses showed a significant result, except for the difference in gender, an interesting result was found: those who knew three languages performed better than the rest of the languages groups. This could be found in the mean scores, the z-scores and in the performance of the participant with the highest score. This may suggest that knowing three languages seems to be ideal when it comes to statistical learning.

It would be interesting to redo this study with some adjustments. The number of participants should be higher, and there should be diversity among the participants: as there were only 31 participants, it is not a very good representation of the population, especially because there was a limited age requirement. The participants should also be tested under the same circumstances, so that different circumstances cannot influence the score of a participant. The test and the questionnaire should be improved (translate everything in the test and add several options in the questionnaire).

As stated before, if previous knowledge from other languages was indeed used in order to learn patterns, it could mean that this knowledge could be used in order to learn a language quicker, as all languages have a statistical structure. New methods could be taken into account in order to make it easier to learn the statistical structure, in order to facilitate learning a new language. However, the results of this study turned out to be not significant enough to prove that knowing multiple languages can improve the ability of learning patterns, but it was found that those who knew three languages were better at seeing the statistical structure in this task. It is thus important to do further research in order to discover if knowing three languages is really the ideal number of languages to learn patterns.
References

(n.d.) Jenny Saffran Retrieved from https://www.waisman.wisc.edu/pi-Saffran-Jenny.htm


Appendix I

Questionnaire

This questionnaire aims at interpreting the results of the test you just took in a better way. Answering all the questions only takes a few minutes! Please answer the questions truthfully and as detailed as possible. These results will only be used for this research and will not be made public.
Thank you very much for your participation!

* Required

Subject number (to be filled out by the researcher): *

Which of the following languages are you (to a certain degree) proficient in? *
- English
- Dutch
- Frisian
- German
- French
- Spanish
- Chinese
- Arabic
- Other:

Language 1: What do you consider to be your mother tongue? *

Language 1: How often and in what context do you use your mother tongue? *

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Almost never</th>
<th>Yearly</th>
<th>Monthly</th>
<th>Weekly</th>
<th>Daily</th>
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<td>At home</td>
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<td>At school</td>
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<td>At work</td>
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<td>With relatives</td>
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<td>With your partner</td>
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<td>When watching radio/television</td>
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<td>When reading books/newspapers</td>
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Language 1: How proficient are you in your mother tongue? *

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<th>Very bad</th>
<th>Bad</th>
<th>Average</th>
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<tr>
<td>Reading</td>
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Are there any other languages, besides your mother tongue, that you are (to a certain degree) proficient in? *
Language 2 to 7

Language 2: What is your second language (the one you acquired after your mother tongue)? *

Language 2: When did you start learning this second language?*
before the age of 3
between 3 and 10
between 10 and 13
after the age of 13

Language 2: How did you learn your second language? *
At home
At school
Other:

Language 2: How often and in what context do you use your second language? *

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<th></th>
<th>Never</th>
<th>Almost never</th>
<th>Yearly</th>
<th>Monthly</th>
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Language 2: How proficient are you in your second language? *

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<th></th>
<th>Very bad</th>
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Are there any other languages that you are (to a certain degree) proficient in? *
Yes
No
Personal information

How old are you? *

Are you male or female? *
Male
Female

Where are you from? *

What do you study? *

Would you call yourself multilingual? *

Would you say that you learn languages with ease? Why (not)? *

Do you have any trouble reading or listening? *

Do you have any language disorder/difficulty with learning a language? *

Link to the questionnaire: https://goo.gl/forms/6aBkXNgro9pazxmH2