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Master's Thesis

How being bilingual can affect your first language.

The effect of age and bilingual language entropy on L1 emotion word processing

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Abstract

This study investigates the impact of bilingualism on the processing of emotion words in the first language (L1) among older adults, with a particular focus on the interplay between age, bilingual language use, and cognitive ageing. As the population of bilingual individuals continues to grow, understanding how emotional cognition is affected by bilingualism becomes increasingly important. This research aims to fill a critical gap in the literature by examining how older bilinguals process emotion words in their L1, considering factors such as valence and bilingual language entropy. Through a lexical decision task in the L1, the study reveals that age-related changes in cognitive processing can influence the emotional resonance of words, highlighting the complexities of emotion-cognition interactions in bilingual contexts. The findings contribute to a deeper understanding of the cognitive advantages and challenges faced by older bilinguals, offering insights into the broader implications for emotional communication and cognitive health in ageing populations.

Keywords: bilingualism, emotion word processing, cognitive ageing, bilingual language use, positivity bias, language entropy

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Introduction

Emotion word processing has been a focal point in bilingualism research, with growing interest in understanding how bilinguals navigate their emotional lexicon in both their first (L1) and second languages (L2). Studies have demonstrated that emotional processing can differ between languages, with bilinguals often reporting stronger emotional resonance in their L1 than L2 (Altarriba, 2008; Pavlenko, 2008). However, much of this research has focused on younger bilingual populations, leaving a gap in understanding how older bilinguals process emotion words—an area critical for understanding bilingualism across the lifespan.

While the cognitive ageing process is known to affect language and emotion processing, studies on older bilinguals remain limited. Older adults tend to show a positivity bias, favouring positive over negative information in emotional processing (Charles et al., 2003). Yet, it remains unclear how this bias interacts with bilingual language processing. Research on emotion regulation in ageing has suggested that older adults may use their emotional experience to prioritise positive information (Mather & Carstensen, 2005), which could affect how they process emotion words in their L1 and L2. While some theories suggest that this phenomenon is caused by normal ageing-related declines affecting the brain (Labouvie-Vief et al., 2010).

Further, bilingualism itself engages cognitive control processes, particularly in tasks requiring language switching and inhibition (Green & Abutalebi, 2013). Considering that people experience normal ageing-related declines in executive function (Mill et al., 2009), it is unclear whether these cognitive changes influence their ability to manage emotional language across languages. Most studies investigating emotion word processing in bilinguals have examined healthy younger participants, whose inhibitory control and working memory are typically intact. Whether healthy older adults experience differences in emotion word processing between their L1 and L2 remains a critical question, as age-related cognitive changes may interact with bilingualism differently than in younger populations.

This study seeks to address these gaps by examining emotion word processing in older bilinguals, focusing on how valence, bilingual language use, and cognitive ageing intersect. By exploring how older bilinguals process emotion words in their L1, this research aims to contribute to the growing body of literature on emotion-cognition interactions in bilinguals while filling the existing gap concerning older populations, which is central as both the number of bilinguals is rising, and people are getting older than ever before.

Emotion Word Processing

Emotions hold more meaning than just the dictionary definitions of their written form. They are evolutionary devices that are meant to keep us alive; especially fear is a good motivator to (not) do things (e.g., to run away from a hungry-looking lion, or to jump back when a car is quickly coming your way) (van Berkum, 2019). However, emotions are not just related to our physical experiences; they are also attached to language and words, so-called emotion words. In linguistic and psychological research, different ways of categorising and describing emotion words have been defined. Emotion words are generally categorised along three dimensions, valence, arousal and emotion-laden vs. emotion-label words.

Words can have a positive, neutral, or negative valence. The valence expresses the extent of the pleasantness or unpleasantness of the affect (Citron, 2012). Example words in English of the three different valence levels would be, *satisfied* (positive), *modest* (neutral) and *irritate* (negative). Arousal, on the other hand, refers to the intensity of the emotional state (Citron et al., 2014), which some people would also call the energy underlying a word (Russel, 2003). For example, while the adjectives *excited* and *content* both have a positive valence, their arousal is different, *excited* is high-arousal and *content* is low-arousal. The third distinction is between emotion-laden and emotion-label words (Wu & Zhang, 2020). The former are words that themselves do not express an emotion, but elicit one (e.g., *birthday cake*), whereas the latter refers to words directly describing an emotion (e.g., *happy*). A word can always be categorised along all three dimensions. For example, the word *orgasm* has a positive valence, is an emotion-laden word and has high arousal (Moors et al., 2013).

Emotion word research often uses these classifications and has shown that especially words with affective features, i.e., words with a positive or negative valence, undergo distinct processing compared to neutral words. Specifically, after accounting for factors like length and familiarity, both negative and positive words demonstrate quicker processing speeds (as measured through reaction times to stimuli) than neutral words during lexical decision tasks (e.g., Kuperman et al. 2014; Kousta et al., 2009). Furthermore, the influence of valence on reaction times in lexical decision tasks is influenced by word frequency: among low-frequency words, both positive and negative words are processed faster than neutral ones, whereas among high-frequency words, positive words exhibit faster processing compared to both neutral and negative words (Scott et al., 2009). While an advantage for negative words has not been documented consistently, a disparity in processing emotion versus neutral words is well-established (Ponari et al, 2015).

The association between valence and processing speed in lexical decision tasks has been documented in various studies. Amongst them, studies on the affective priming effect. An affective priming effect occurs when two words elicit faster and more accurate responses because they share the same emotional valence (Yao et al., 2019) but they do not have to be semantically related (Ferré & Sánchez-Casas, 2014), for example, *harmony* and *success,* which both have a positive valence but are semantically incongruent. In an experimental setting, this means that a positive prime would speed up the reaction to a positive target. Yao et al. (2019), for example, found, in their lexical decision-priming task experiments, that valence had a stronger effect on affective priming than arousal or the interaction between them. This is an important factor to consider when designing a study using emotion words, one way of doing that is to pseudo-randomise the items to prevent too many of the same valence following one another. Especially positive valence seems to impact language processing speed as opposed to negative or neutral valence.

In lexical decision tasks, reaction times, which are used as an indicator of processing speed, are consistently faster for positive valence items (e.g., *puppy*) compared to negative items (e.g., *lonely*) (e.g., Kazanas & Altarriba, 2015; Crossfield & Damian, 2021), highlighting how emotional information influences language processing in this research paradigm. Possible reasons for this could be that positive stimuli are associated with rewards (Kissler et al., 2007) or elicit less cognitive interference than negative items do (Schmidt & Saari, 2007). Negative stimuli are also more likely to activate threat-detection systems and therefore might take longer to disengage from this state of heightened arousal (Kuperman et al., 2014). Additionally, emotion-label words have a stronger effect on affective priming than emotion-laden words (Kazanas & Altarriba, 2015). Without priming, positive items (e.g., *celebration*) also yield faster reaction times compared to negative (e.g., *amputation*) and neutral (e.g., *cactus*) items, where negative items had quicker reaction times than neutral one (Crossfield & Damian, 2021). Research findings have been not as straightforward for negative and neutral items. Some indicate that negative items are reacted to faster (Crossfield & Damian, 2021), while others find a slight advantage for neutral items (Kuperman et al., 2014). This seems to indicate that positive valence has the biggest influence on emotion word processing in terms of processing speed as compared to negative or neutral valence.

People process emotion words differently, as factors such as personal experiences (Siakaluk et al., 2014), mental (Klumpp et al., 2010) and physical health (Kiecolt-Glaser et al., 2002), bilingualism (Altarriba, 2008), and age (Lynchard & Radvansky, 2012) might influence it. The following sections will delve into the impact of bilingualism and age on emotion word processing. Before that, an overview of bilingualism and two frameworks defining the bilingual experience will provide a foundation for understanding our research approach, methods, and how these frameworks inform the theoretical and practical aspects of this study. This excursion will clarify key concepts and their relevance to the findings.

Bilinguals and the Bilingual Experience

The bilingual experience of every person is different. Especially factors such as age of acquisition (Ellis & Lambon Ralph, 2000) and proficiency (Blumenfeld & Marian, 2013) impact participants' reaction times and accuracy on lexical decision tasks. Past studies have shown that early bilinguals, who have acquired their second language before or around the age of 5, have faster reaction times than late bilinguals, who have acquired their L2 later than 5 years old, on a monolingual lexical decision task in their second language (Pangilinan et al., 2014). Higher proficiency also facilitates access to words in the second language, because of more exposure and a better feeling for the language (Tribushinina et al., 2020).

Executive Control

Studies have found that bilinguals develop enhanced executive control through the need to manage multiple languages (Bialystok et al., 2012; Hilchey & Klein, 2011; Costa et al., 2008). Executive control refers to a set of cognitive processes that are essential for the cognitive control of behaviour. These enable an individual to plan, focus attention, remember instructions, and juggle multiple tasks successfully. The key executive control processes, which are central to broader cognitive function, include inhibitory control, working memory, cognitive flexibility, planning and problem-solving, and attention control.

Inhibitory control stands out as a key process, enabling individuals to suppress distractions and impulses, and to maintain focus on a task at hand. This includes controlling attention and behaviour, resisting temptations, and inhibiting automatic or dominant responses (Diamond, 2013). Inhibition is internally focused as opposed to ignoring distractions, which is normally externally focused, where you try to filter out irrelevant environmental stimuli. Another process is working memory, which is the capacity to hold and manipulate information over short periods. Working memory is essential for reasoning, learning, and comprehension (Diamond, 2013). Cognitive flexibility, another executive control process and, is the ability to switch between different tasks or mental states. It allows for adaptability to new and unexpected conditions and the ability to think about multiple concepts simultaneously (Diamond, 2013). This is also relevant for the next processes, planning and problem-solving. They are the capability to formulate, evaluate, and implement strategies to achieve goals. This involves setting objectives, devising plans, monitoring progress, and making necessary adjustments (Drigas & Karyotaki, 2019). Lastly, there is attention control, which is the ability to focus on relevant information while ignoring distractions. This includes both sustained attention (maintaining focus over time) and selective attention (focusing on specific stimuli) (Fisher, 2019).

Bilingual advantages, in which bilinguals outperform their monolingual peers, have been observed for certain executive control processes, such as working memory and inhibitory control (for a review, see: Bialystok et al., 2009). Such observations have been made for young children for enhanced attention control and inhibitory control (Bialystok & Martin, 2004) and cognitive flexibility (Carlson & Meltzoff, 2008; Adi-Japha et al., 2010, Bialystok & Viswanathan, 2009), for young adults for enhanced inhibitory control (Costa et al., 2008) and cognitive flexibility (Prior & MacWhinney, 2010), as well as for older adults for enhanced inhibitory control (Salvatierra & Rosselli, 2010) and working memory (Bialystok et al., 2004). An explanation for this could be that bilinguals face more demanding language control requirements due to the constant monitoring of two languages or more and that these demands might enhance executive control.

However, findings on a bilingual advantage are not as consistent as they might seem. While some research and even meta-analyses (Adesope et al., 2010) do find a bilingual advantage for certain executive control processes, recent research has also shown that bilingual advantages may be eliminated depending on the data trimming procedure (Zhou & Krott, 2015). Moreover, recent studies comparing executive function between bilinguals and monolinguals have frequently found no significant differences in performance (Paap et al., 2015). Furthermore, critique of a publication bias was brought forth, that both researchers and publishers were favouring studies presenting a bilingual advantage than those with null results or even negative results (de Bruin et al., 2015).

These mixed results on a bilingual advantage for executive control underscore the complexity of bilingualism's impact on cognition and the need for continued, rigorous research to unravel its nuances.

Two Recent Frameworks on Bilingualism

Language Entropy. A recent way to measure the bilingual experience without depending on only individual variables such as age of acquisition or proficiency is to calculate participants' language entropy, which gives a measure on the participant's diverse use of their languages. This allows for the bilingual experience to be interpreted in a continuous manner while focussing on how balanced the current use of their respective languages is, which is how we will be measuring bilingualism in this study. Language entropy measures how evenly or diversely two or more languages are used in daily life (Gullifer & Titone, 2020). In short, language entropy measures an individual's language diversity. Entropy, which originally comes from information theory, is a measure of uncertainty in a set (Shannon, 1948), which can be a collection of practically anything, both concrete or abstract, e.g., information content, books, or also languages. Higher entropy suggests greater complexity or diversity, while lower entropy implies more order or predictability.

In contexts where there is more variability in the languages that are being used (i.e., when they are used in a balanced way, such as speaking both Dutch and English in equal amounts at university), the predictability of which language to use is low. For language entropy, high entropy suggests an integrated language use, where all languages are used equally. This unpredictability is also affected by the number of languages spoken by a person: the more languages and the more integrated they are being used, the less predictable. Low entropy represents a compartmentalised language use, where only one language is used in a context, for example only speaking English at work. In a context where one language is used much more often than the other(s), it is easier to predict which language will be used. For example, a person might speak exclusively English at work and then use exclusively Dutch at home. The time spent using each of the two languages might be similar, making it seem as if they are used in a balanced way because one is not used more dominantly than the other. However, due to each of the two languages being only spoken in a very specific context (i.e. being compartmentalised to only one context) the predictability of the choice of language is quite high, which means that entropy is quite low.

Language entropy provides a quantifiable measure of how individuals distribute their language use across different communicative contexts, capturing the dynamic balance of linguistic input. This concept aligns with broader cognitive theories such as the Adaptive Control Hypothesis (Green & Abutalebi, 2013), which posits that bilinguals and multilinguals constantly adjust their cognitive control mechanisms to manage competing language demands. The hypothesis suggests that varying contexts of language use shape and modulate cognitive control systems, influencing performance on tasks requiring attention and flexibility. Thus, the interaction between language entropy and cognitive control processes, as proposed in the Adaptive Control Hypothesis, can offer insights into how multilingual individuals adapt to shifting linguistic environments.

The Adaptive Control Hypothesis. It provides a framework for understanding how bilinguals manage their two languages and how this management influences cognitive control processes (Green & Abutalebi, 2013). According to the hypothesis, the need to switch between languages and inhibit one (or multiple) language(s) while using another leads to enhanced executive control abilities. It postulates that language control processes adjust in response to the recurring demands imposed on them by the interactional context (Green & Abutalebi, 2013). It proposes that the demands on language control processes in bilingual speakers depend on the interactional context and that they set their control processes' parameters accordingly so that they are well-coordinated with the other control processes employed in the interactional context.

The Adaptive Control Hypothesis emphasizes that the type and frequency of language use in different interactional contexts affect the degree of cognitive control required. The three primary contexts described are: (1) single-language contexts, in which one language is used exclusively in certain environments. This requires minimal switching and lower cognitive control demands. (2)

Dual-language contexts, where one switches between languages in different situations or with different interlocutors. This requires frequent switching and high cognitive control demands, especially due to the need of inhibiting the other language(s). (3) Dense code-switching contexts, in which frequent switching between languages within the same conversation or sentence occurs. The frequent switching within the same conversation requires moderate cognitive control due to constant monitoring and switching.

There are eight control processes that are central to managing bilinguals' languages across various interactional contexts, as conceptualized in the Adaptive Control Hypothesis. Lai and O'Brien (2020) further describe how specific control processes are activated in dual-language and dense code-switching contexts:

> In the dual-language context, the process of **goal maintenance** is activated when the bilingual must establish and maintain a task such as speaking in one language rather than another (Green and Abutalebi, 2013). This maintenance requires interference control processes (interference control), which is proposed to be related to two control processes of **conflict monitoring** and **interference suppression**. The process of **detection of salient cues** is also important in successful communication as the detection of changes in the interactional context (e.g., arrival of another speaker) might require the bilingual to switch and use their other language (salient cue detection). The bilingual has to prevent themselves from continuing to speak in the current language, using **selective response inhibition**. This then triggers the need for the bilingual to disengage from the current language. In order to switch languages effectively, the bilingual will have to disengage from the previous language and activate the new one (**task engagement** and **disengagement**). Accordingly, the dual-language context is proposed to be associated with cognitive monitoring and inhibitory control processes. […] In the dense code-switching context, distinct effects on opportunistic planning control processes are proposed (**opportunistic planning**). By using whichever language is most readily available, bilinguals adapt words

from one language to fit into another and languages are used opportunistically (intra-sentential switching). (p. 2; emphasis added)

It is relevant to mention that, compared to monolingual speakers in a monolingual context, bilingual speakers in all three interactional contexts are said to have increased demands regarding all 8 control processes (Green & Abutalebi, 2013). Especially in the dual-language context, an individual is assumed to show an increase in demands on 7 out of the 8 control processes, all except opportunistic planning, with a special focus on goal maintenance and the two interference control processes, conflict monitoring and interference suppression (Green & Abutalebi, 2013). The hypothesis predicts that bilinguals who frequently switch languages, particularly in dual-language contexts, will develop stronger executive control skills, especially for inhibitory control, than monolinguals or individuals that mostly experience single-language contexts (p. 522). This enhancement is due to the regular practice of managing two languages and the need to resolve linguistic competition.

While these three interactional contexts cannot be fully compared to the integrated and compartmentalised language uses described for language entropy, the two models do still complement each other nicely and show the nuances of bilingual language use, with the Adaptive Control Hypothesis proposing how the different contexts impose different demands on the cognitive system. The Adaptive Control Hypothesis provides a theoretical framework for the cognitive control mechanisms involved in (bilingual) language control, while language entropy offers a more quantitative measure that aligns with the adaptability and integration proposed by the Adaptive Control Hypothesis in capturing the bilingual experience. However, it is important to highlight that language entropy does not directly correspond to the interactional contexts proposed in the Adaptive Control Hypothesis, as it fails to distinguish between dual-language and dense code-switching contexts (van den Berg et al., 2022). While the Adaptive Control Hypothesis emphasises the dynamic and situational demands of different interactional contexts, language entropy provides a more stable, overarching measure for capturing long-term patterns of bilingual language use. Together, these frameworks enrich our understanding of the cognitive and contextual complexities of bilingualism, even as each has its limitations in capturing the full spectrum of bilingual language behaviour.

As discussed at the beginning of this section, the bilingual experience is highly variable, influenced by individual histories and the contexts in which languages are used. However, it is these very contexts, whether related to cultural background, language acquisition, or daily interactions, that may influence how bilinguals process emotions. The following section will now explore how bilingual individuals process emotion words, and how factors such as language proficiency and context of language use shape processing of emotional content in their first and second languages.

Emotion Word Processing in Bilinguals[1]

It has been said about bilingual individuals that they experience emotions less strongly in their second or subsequent languages (Pavlenko, 2005), that emotion words or taboo words in their L2 mean less to them and seem less strong (Dewaele, 2008), while they also self-report experiencing emotions more strongly when they are presented in their native language (Altarriba, 2008; Pavlenko, 2008). One theory behind this is that this is caused by them often learning the second or subsequent language later in life, after affective associations have been established during childhood (Pavlenko, 2012). Another reason could also be the setting in which a language has been learned, that learning a language in a classroom does not provide enough affective associations within that language and emotion words to form such strong bonds, leading to "disembodied" words, that are being used freely without knowing or feeling their full impact

1 If not mentioned otherwise in studies on bilingualism discussed in this thesis, we will continue using the very broad term *bilingual* without specifying the beforementioned language use contexts. A lot of past research has not considered the bilingual language use contexts of their participants or at least does not mention it explicitly in the publications. For the time-being, this generalisation into *bilinguals* will has to be made until more research explicitly includes the language use contexts of their bilingual participants.

(Dewaele, 2008; Pavlenko, 2012), such as saying *I love you* in a second language might seem less scary or strong than saying it in the L1.

However, when looking at objective measures, such as RTs, instead of self-reported experiences, there are inconsistent results, which span the whole spectrum from a processing advantage for emotion words in their L1 (e.g., Ferré et al., 2018), to no difference between individuals processing their L1 and L2 (e.g., Segalowitz et al., 2008), all the way to an advantage in their L2 (e.g., Kazanas & Altarriba, 2016). Despite the well-established tendency in emotion word processing in monolinguals, most notably the robustly attested finding that positive valence words facilitate processing, there are still areas that have not been researched as heavily, which might have more variability depending on certain factors, such as the effect of being bilingual and how integrated the language use of these languages might be.

Studies examining the impact of valence and language on word processing in bilinguals reveal nuanced effects influenced by language proficiency, dominance, and emotional content. Ferré et al. (2018) demonstrated that valence significantly affects response times and recall in balanced Catalan-Spanish bilinguals, with slower reaction times for negative words and enhanced recall for positive words. When the same paradigm was extended to include a less-proficient third language (i.e., English), positive words elicited the fastest response times, and Spanish (the dominant language) showed both faster reaction times and higher accuracy than English, emphasising the role of proficiency in emotion word processing.

In contrast, Kazanas and Altarriba (2016) found that Spanish-English bilinguals processed positive words faster in their L2 (i.e., English) than their L1, exhibiting a positive valence effect in both languages. Language dominance also influenced outcomes, as English, the participants' functionally dominant language, yielded faster reaction times. This finding challenges the idea that classroom-acquired languages lack sufficient affective associations for robust emotional processing.

The two studies presented above offer valuable insights into the complexities of bilingual cognition and emotional processing. They present findings that support a usage-based approach to the differences in bilingual processing, which show how proficiency and usage amount can have a big impact on subconscious language and emotion word processes. They highlight the dynamic interplay between language proficiency and environmental factors. Another environmental factor that can have an impact on emotion word processing is age, which will be discussed in the following section.

The Effect of Age on Emotion Word Processing

Despite the research on the processing of emotion words and how this interacts with bilingual life experiences, it is yet unclear how age might impact bilingual emotion word processing. What is known is that older adults, often taken to denote people aged 60 or older, generally process emotions and emotion words with extra attention being put on positive emotions and information (Charles et al., 2003), emotional regulation, such as being less likely to engage in counterproductive or damaging actions (Mather & Carstensen, 2005), and contextual understanding (Samanez-Larkin et al., 2009), whereas younger adults are more likely to engage deeply with both positive and negative emotions (Labouvie-Vief, 2003) and focus more on specific details than the overall context (Kensinger & Schacter, 2008). This “extra attention” that is being put on positive emotions has been coined *the positivity effect* or also *positivity bias*, which refers to an age-related trend in which positive stimuli are favoured over negative stimuli in processing (Reed & Carstensen, 2012). It has been shown in both linguistic and psychological research that especially older adults recall and recognise positive information better than negative or neutral information (Charles et al., 2003).

Research on emotional memory processing in older and younger adults highlights a shift in how emotions are recalled and processed with age. Older adults tend to exhibit a positivity effect, where they recall more positive than negative or neutral stimuli, particularly when the emotional content is non-arousing (Charles et al., 2003; Kensinger, 2008). In contrast, younger adults often show a negativity bias, remembering negative items more readily than positive ones (Charles et al., 2003). This effect is also influenced by perspective, as shown by Lynchard and Radvansky (2012), who demonstrated that when participants adopted the perspective of an older individual, both younger and older adults exhibited a positivity effect, whereas a negativity effect was observed when adopting a younger perspective. These findings collectively suggest that age and perspective play a significant role in how emotional content is processed, with older adults showing a preference for positive emotional information in both memory recall and response to stimuli (Charles et al., 2003; Kensinger, 2008; Lynchard & Radvansky, 2012).

The cause for the increased positivity effect with age is a debated topic, with at least two possible approaches. On the one hand, it could be caused by cognitive degradation. This means that, as our brains naturally decline in normal ageing, we develop a positivity bias due to positive emotions being easier to process (Labouvie-Vief et al., 2010), which could be because they do not produce as much cognitive interference as negative emotions do (Schmidt & Saari, 2007). Considering the cognitive benefits bilinguals accumulate throughout their lifetime, it could be expected that older lifelong bilinguals, those with bigger cognitive reserve (which will be explained in more detail in the following section), might exhibit a smaller positivity effect than older lifelong monolinguals if one believes in the cognitive degradation account of the positivity effect.

On the other hand, the positivity bias could be caused by motivation. This can be explained as, as we get older and gain more experiences, we may notice that focussing on the negative things in life is not useful or healthy and might therefore develop a positivity bias (Mather & Carstensen, 2005). The debate surrounding the increased positivity effect with age offers contrasting perspectives, suggesting that while cognitive degradation may contribute to the bias, motivational factors could also play a significant role. Further research exploring the interplay between cognitive decline, motivational shifts, and the positivity bias in ageing populations could provide valuable insights into the underlying mechanisms driving this phenomenon.

Ageing Bilinguals

The before mentioned executive control processes also decline with age. Older adults typically exhibit slower processing speed compared to younger adults due to natural ageing-related declines (Mill et al., 2009), they also exhibit more variability in their response times than younger adults (Hultsch et al., 2002). The slower processing speed can affect various aspects of executive control, such as working memory updating and task switching. They might also experience decreased working memory capacity. Working memory capacity tends to decline with age, which can impact the ability to hold and manipulate information during complex cognitive tasks (Peich et al., 2013). However, lifelong bilinguals (i.e., people that have been bilingual their whole live) have built up cognitive reserve that might help preserve executive control abilities in later life (Gold et al., 2013; Liu & Wu, 2021).

Building up cognitive reserve means that individuals would retain normal functioning of the brain, despite a potential decline setting in (Bialystok et al., 2021). Cognitive reserve can be understood as the brain's resistance to letting neuropathological damage affect an individual's behaviour. It is how efficiently and flexibly an individual completes a task with the brain resources still available to them (Bigler & Stern, 2015), whether that is through the brain recruiting alternative brain networks or regions to compensate for the loss (Grefkes & Fink, 2014) or maybe also through the individual adopting new cognitive strategies to accomplish tasks (Belleville et al., 2011). Various factors have been found to contribute to cognitive reserve, these include higher levels of education (Stern, 2002), intellectually demanding occupations (Stern, 2009), active engagement in social and leisure activities (Geda et al., 2011) as well as being bilingual (Bialystok et al., 2024). This has been supported by findings that bilinguals start showing Alzheimer's symptoms several years later than their monolingual peers (Weissberger et al., 2019), as well as bilingual brains presenting more atrophy than monolinguals with similar symptoms (Schweizer et al., 2012), which means that more neurodegeneration is necessary in patients with high cognitive reserve before a disease manifests. Cognitive reserve plays a crucial role in maintaining cognitive function and delaying the onset of clinical symptoms in the face of neurodegenerative conditions, underscoring the importance of lifelong mental engagement and activities such as bilingualism. While ageing-related declines in executive control processes are common among older adults, the cognitive reserve accumulated through lifelong bilingualism may offer a protective factor, potentially mitigating some of these declines and supporting continued cognitive vitality in later life.

Research Questions & Hypotheses

The review of existing literature has highlighted gaps in understanding the role of bilingualism in ageing populations. While prior studies have extensively explored emotion word processing, the impact of bilingualism on this process, particularly in ageing individuals, remains underexplored. To address this gap, the present study investigates how bilingualism may influence first-language processing in differently aged populations. This investigation is guided by a set of carefully formulated research questions and hypotheses. The following section presents these guiding questions and theoretical predictions, which provide the foundation for the empirical analysis.

The first research question is aimed at replicating the findings that positive stimuli have the fastest reaction times (e.g., Kensinger, 2008; Kazanas & Altarriba, 2015). Therefore, the question is how does emotional valence influence reaction times in a Dutch lexical decision task. In line with former research, we are expecting a positivity effect, which will show through faster reaction times for positive items, while neutral items will be reacted to the slowest.

Secondly, we will be looking at how age will affect reaction times in a Dutch lexical decision task. For this, we are expecting slower reaction times for the older adults compared to the younger control group due to natural ageing-related declines in processing speed (e.g., Mill et al., 2009; Bialystok et al., 2008).

The third research question is concerned with emotional valence and age, where it is of interest to observe how emotional valence influences reaction times in older Dutch adults. We are expecting a similar reaction times pattern for the different valence categories irrespective of age group, i.e., that positive items will have the fastest reaction times. Neutral items will have the slowest reaction times, and negative items will be in the middle. However, we expect there to be a significant difference in reaction times between positive and negative items for the older adults, while the difference in RTs for younger adults will be smaller. This is due to older adults responding significantly faster to positive items than negative or neutral items, whereas the response gap between positive and negative items is smaller for younger adults (Kensinger, 2008; Ponari et al, 2015).

Considering the new perspective language entropy offers for measuring bilingualism (specifically, examining how two or more languages are used in daily life) it becomes intriguing to analyse its potential impact on reaction times in a Dutch lexical decision task. Higher language entropy scores are associated with better executive function in bilinguals, which implies, among other things, enhanced inhibitory control (Bialystok et al., 2008). This control is essential for suppressing other languages during the lexical decision task. Consequently, the hypothesis is that higher language entropy scores will result in faster reaction times compared to lower entropy scores.

Two follow-up questions regarding language entropy have also been formulated. The first one is concerned with emotional valence and language entropy, namely, how bilingual language entropy influences the processing of differently valenced words. Combining our hypotheses for emotional valence and language entropy, we hypothesise that participants with higher language entropy scores will react faster to positive stimuli, because they will be showing better inhibitory control (Green & Abutalebi, 2013), than participants with lower language entropy scores. Comparable to the hypothesis for emotional valence, we believe that the order of reaction times per valence will be the same, however, participants with higher language entropy scores will react faster.

The second follow-up question, and final research question, looks at how bilingual language entropy affects the reaction times of older adults in a Dutch lexical decision task. The hypothesis is again that faster reaction times will be recorded for participants with higher language entropy scores compared to participant with lower entropy scores. However, considering that older adults generally have slower reaction times, we expect older participants with higher language entropy scores will have RTs similar to the participants with lower language entropy scores from the younger control group.

Methodology

Participants

This study analysed the data from 29 older Dutch native speakers (44% women, 56% men) and 20 younger Dutch adults (75% women, 25% men), who formed the control group. Their eligibility was determined based on the following inclusion criteria: they were either at least 60 years old (mean age: 69.1; *SD* = 8.32), or for the control group between 18 and 35 years old (mean age: 24; *SD* = 2.36), they were native speakers of Dutch, spoke more than one language, and they did not have dyslexia. These requirements were surveyed through a questionnaire, before granting access to the actual experiment. Participants received €15,-- monetary compensation for their participation. Due to financial restrictions, the participants in the control group did not receive monetary compensation, however, upon completion of the experiment they were entered into a raffle to win a €15,-- gift card that can be used in a variety of stores. Informed consent was obtained from all participants.

At the beginning of the study, prospective participants were contacted through various sources, amongst them the senior higher education centre *HOVO* (*Hoger Onderwijs Voor Ouderen* offers courses on an academic level to people in the North of the Netherlands that are 50 years old or older.), *DenkTank 60+ Noord* (The Think Tank is a networking organisation focused on the participation of older people in society.), *Oud Geleerd Jong Gedaan* (The foundation offers interactive lectures to older people, delivered by students, with focus on intergenerational contact and lifelong learning.), two senior centres in Utrecht, various Facebook groups that contained Dutch native speakers, and the researchers' own social network. For the control group, recruitment happened through the researcher's own social network and social media platforms, such as Facebook and LinkedIn, as well as through hanging up flyers in the university buildings and the public library in Utrecht.

The experiment was approved by the Research Ethics Committee (CETO) of the Faculty of Arts, University of Groningen (reference number: 98271971) and the Faculty Ethics assessment

Committee of the Faculty of Humanities (FEtC-H) at Utrecht University (reference number: 24-022-01). The financial reimbursement for the older participants came out of the personal budget of dr. Merel Keijzer, PI of the Bilingualism and Aging Lab at the University of Groningen.

Materials

Language Background Questionnaire

Participants completed a questionnaire to collect information on the use of their languages and their language background. For this, an adapted version of the Dutch version of the *Language Experience and Proficiency Questionnaire* (LEAP-Q; Marian et al., 2007, translated by Lisa Vandeberg) was used. The LEAP-Q covers questions on the languages the participants learnt and their proficiency for them, their current exposure to them, age of acquisition for each language and the order in which they acquired them. We further included questions on the extent to which they spoke each language in four communicative contexts (i.e., home, work, university, and social settings) and their switching habits (e.g., Please rate the amount of time you *actively* use the following language(s)/dialect(s) in social settings on a scale of 1-7. 1 = no usage at all, 7 = all the time). With this data, we were able to calculate the language entropy scores of each participant and used this as the variable for bilingualism during the data analysis. The full questionnaire can be found in Appendix B.

Lexical Decision Task

The stimuli for the lexical decision task consisted of 30 items per condition (i.e., positive, neutral and negative) and a matching number of non-words created with the pseudoword generator *Wuggy* (Keuleers & Brysbaert, 2010), summing up to 180 stimuli. To generate the non-words, one has to enter existing words into *Wuggy*. The generator then creates non-words, which are based on the real words entered, that adhere to the phonotactic rules of the language chosen by the researcher. The stimuli were taken from Moors et al. (2013), who pretested the items for their valence, arousal, and power or dominance. The stimuli were selected according to these criteria: they were 5 to 9 characters long and they were nouns and adjectives or adverbs, the majority of items were nouns (71%). Items have been qualified as positive valence words if they had a mean score of at least 5.85 on a 7-point scale, as neutral if their mean score was between 3.84 and 4.45, and as negative if their mean score was between 1 and 2.22. The cut-offs were picked so that each category occupied an area of the mean valence range that was the most representative (i.e., as low as possible for negative items and as high as possible for positive items) and had a minimum of 30 items in it, also considering the mean arousal and frequency scores, which is the reason why the cut-offs are not neat numbers. The items' mean arousal scores lay between 4.00 and 5.41, also on a 7-point scale. Further, the frequency of the items was considered, which led to the items of all three valence levels having a frequency between 1.00 and 2.42 (log10 of frequency per million words). The list of all word stimuli and the non-words is in Appendix A.

Table 1

Summary of Stimuli

	Valence		Arousal		Frequency	
	M	SD	M	SD	M	SD
Positive	6.16	0.08	4.61	0.20	1.60	0.40
Neutral	4.19	0.23	4.48	0.14	1.54	0.36
Negative	2.03	0.15	4.79	0.20	1.39	0.31

Note. Summary of stimuli with means (M) and standard deviations (SD) (rounded to two decimals) for valence, arousal and log10 frequency per million words for each of the three valence categories.

The stimuli were randomised beforehand using the program *Mix* (van Casteren & Davis, 2006), and 450 pseudo-randomised lists were saved in individual .csv files. A simple randomisation method was used, where each participant saw every stimulus once but in a different order. The order of stimuli was random, but with no more than 2 per valence category, including non-words after one another, thereby avoiding an unintentional priming effect. For every participant, a random number between 1 and 450 was generated by OSWeb, which decided which stimuli list was taken.

Procedure

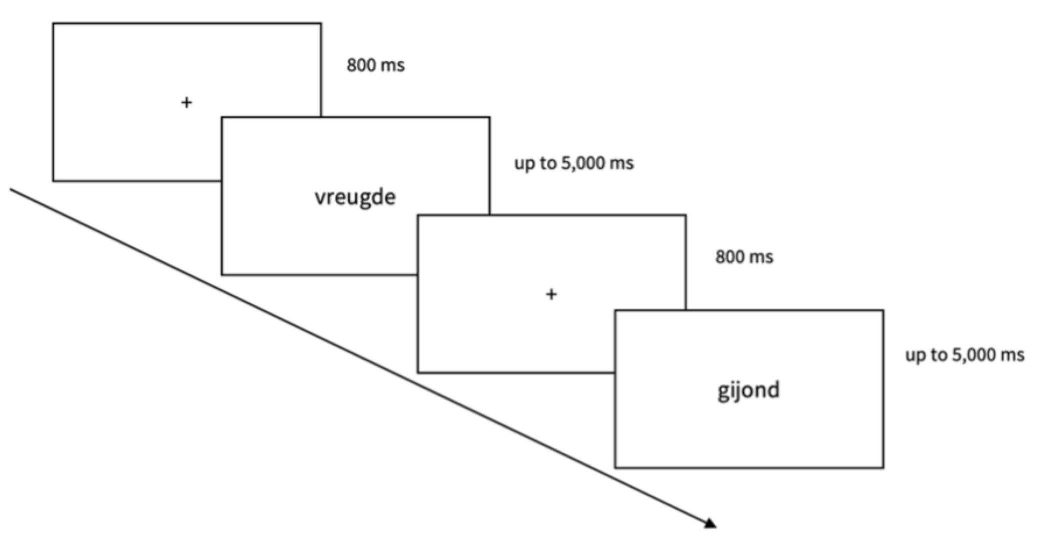
Participants first provided written informed consent online. Subsequently, they were presented with a language background questionnaire adapted from the LEAP-Q, which was hosted on the online survey platform Qualtrics, Versions March to August 2024 of Qualtrics (Qualtrics, Provo, UT), to determine their eligibility and control for possible confounds. If eligible, they were forwarded to the lexical decision task, where they were given instructions. Then participants were presented with a practice trial that consisted of 6 stimuli, one for each valence category and a corresponding non-word. During this practice trial they were also given visual feedback in the form of green (i.e., correct) or red (i.e., incorrect) stripes above and below the stimulus to see whether their response was correct. Afterwards, they were presented with Dutch words with positive, neutral, and negative valence and non-words that followed the phonotactic constraints of the Dutch language. The stimuli had to be judged as real words or non-words by pressing the “A” and “L” keys on a physical keyboard.

The experiment was a remote, online lexical decision task, where participants used their own computers or laptops. Word and non-word stimuli were presented in a black lowercase Droid Sans Mono font, size 32, on a white background using the OSWeb extension of OpenSesame (Mathôt et al., 2012). The experiment’s interface was adapted from an OpenSesame template provided by the OpenSesame software. The experiment is stored on the MindProbe server, which is sponsored by the European Society for Cognitive Psychology (ESCOP), on the open-source software JATOS (Lange et al., 2015).

Every participant was presented with all 180 trials as follows. First, the participant looked at a fixation cross at the centre of the screen for 800 ms after which the trial started. The stimulus remained on the screen until the participant responded or 5,000 ms elapsed to ensure enough time for responses. Despite this, participants were instructed to respond as fast and as accurately as possible. The experimental procedure of the lexical decision task is illustrated below in Figure 1.

Figure 1

Illustration of the Experimental Procedure Used in the Lexical Decision Task



Analysis

Calculating Language Entropy Scores

Language entropy scores were derived from the participants' self-reported language use data from the questionnaire for their first and second language, and subsequent languages up to their fifth, if available, across various communicative contexts, namely home, university, work, social settings, reading, and speaking. To calculate language entropy scores for each context the *languageEntropy* package in R (Gullifer & Titone, 2018) was used. For the contexts of home, university, work, and social interactions, language use data was collected through Likert scale ratings, prompted (in Dutch) by: "Please rate the amount of time you *actively* use the following language(s)/dialect(s) in [context] on a scale of 1–7 (1 = no usage at all, 7 = all the time)." Following the protocol of Gullifer and Titone (2020), these Likert scores were adjusted by subtracting 1, making a score of 0 represent “no usage at all” and the highest score therefore being a 6 for “all the time”. These adjusted scores were then converted into proportions by dividing each language’s score by the total score of each of the four contexts. For reading and speaking contexts, participants reported language use as percentages, answering questions such as, “When choosing a language/dialect to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language/dialect?” These percentages, which needed to sum to 100% for each context, were converted into proportions and used to compute entropy values for each of the two contexts. Language entropy, which is based on Shannon’s entropy formula, which described the likelihood or probability of something happening (1948), such as choosing a specific language in a given context, was calculated using this equation:

$$H = -\sum_{i=1}^{n} P_i \log_2(P_i)$$

In this formula, n represents the number of languages in a given context, and P_i denotes the proportion of usage for each language i. An entropy score of 0 signifies exclusive use of a single language within a context. For a bilingual individual who uses two languages equally, the entropy score would approach 1, while for three languages, the entropy score would approximate 1.60, indicating balanced usage across the three languages. For four languages, a balanced use would be indicated by a score of approximately 2, while for five equally used languages, the entropy score would be approximately 2.32. However, a non-balanced use of two languages could look like this, for example: if a participant reported using Dutch 70% of the time and Spanish 30% of the time within the university context, language entropy would be computed by summing 0.70*log_2(0.70) and 0.30*log_2(0.30). This total is then multiplied by -1 to yield a positive entropy value. This participant’s language entropy score in the university context would be approximately 0.88. As a reminder, the higher the score is, the more integrated the languages are, the more balanced the languages are used.

For each participant, the language entropy scores of each context were averaged out into one overall language entropy score with which the analysis was conducted. The final scores were then separated into three equally sized groups of around 15 participants according to the height of the score to simplify the analysis, while still keeping some nuance with the three instead of only two groups. They were separated into low, medium and high scores.

Reaction Times

To examine the differences in reaction times across levels of valence, age groups and language entropy groups, pairwise comparisons were conducted using estimated marginal means (EMMs) in R version 2024.4.2.764 (R Core Team, 2024). This approach was chosen as it accounts for the model structure and provides adjusted means for each factor level, controlling for covariates or other predictors included in the statistical model.

A linear mixed-effects model was first fitted to the data using the *lmer* function from the *lme4* package (version 1.1-27.1; Bates et al., 2015). It is a hypothesis model and was done without looking into model comparisons. In the fixed structure of the model, there were factors for age group (older adults versus younger adults), valence (positive versus neutral versus negative), and language entropy groups (low versus medium versus high). In the random structure of the model, there was one factor for participant and one for trial number. These are included in the model to account for the possibility that participants may show individual fatigue patterns (i.e., in some cases, reaction times may increase as the number of completed trials increases). This resulted in the following model specification:

response_time ~ valence * age_group * language_entropy_groups + (1|participantID) + (1|trial_number)

Pairwise comparisons between factor levels for both main and simple effect were then conducted using version 1.10.4 of the *emmeans* package (Lenth, 2024), which computes estimated marginal means and their corresponding contrasts. To control for Type I error inflation arising from multiple comparisons, Tukey's adjustment was applied for the valence and the language entropy score variables. This adjustment ensures that the reported p values reflect an appropriate balance between statistical power and the risk of false positives.

The pairwise comparisons provided both the magnitude of the differences (e.g., mean differences with confidence intervals) and their statistical significance through p values. These comparisons were visualised using version 3.5.1 of the *ggplot2* package (Wickham, 2016) and version 2.8.16 of the *sjPlot* package (Lüdecke, 2024), facilitating the interpretation of differences among factor levels.

Results

Three participants, two older adults and one younger adult, had to be excluded from the analysis as their accuracy on the lexical decision task was far below 70%. When looking at the individual responses it was visible that the older adults pressed a wrong key for the non-word responses, which meant that the response time was recorded as the full 5.000 ms that were possible for each item and therefore no answer was recorded. The younger adult had reacted in a manner that indicated that they were just pressing a single key to get through the experiment quickly. Therefore, the results of 27 older adults and 19 younger adults were considered for the analysis.

For clarity and organisation within this paper, all tables presenting the emmeans analysis output for both main and simple effects can be found in Appendix C, arranged in the order of the hypotheses which mirrors the order in which the results are presented here.

The Effect of Age on RTs

The emmeans analysis of the main effects revealed a significant difference in reaction times between the two age groups. Specifically, older adults exhibited slower reaction times compared to younger adults, with an estimated difference of 262 ms (SE = 51.5, $t(40) = 5.078$, $p < .0001$). These findings suggest that age plays a significant role in influencing reaction times, with older adults processing lexical items more slowly than their younger counterparts.

Table 2 shows the mean reaction times per age group (also divided into the three valence categories, which will be discussed in a later section), which also clearly indicate a significant difference between older and younger adults.

Table 2

Mean Reaction Times per Age Group

	Younger Adults		Older Adults	
Valence Levels	RTs	SD	RTs	SD
Positive	566.69	165.94	821.58	300.17
Neutral	580.44	160.36	822.22	306.13
Negative	600.71	143.67	864.78	351.95
	582.41	157.60	836.08	320.62

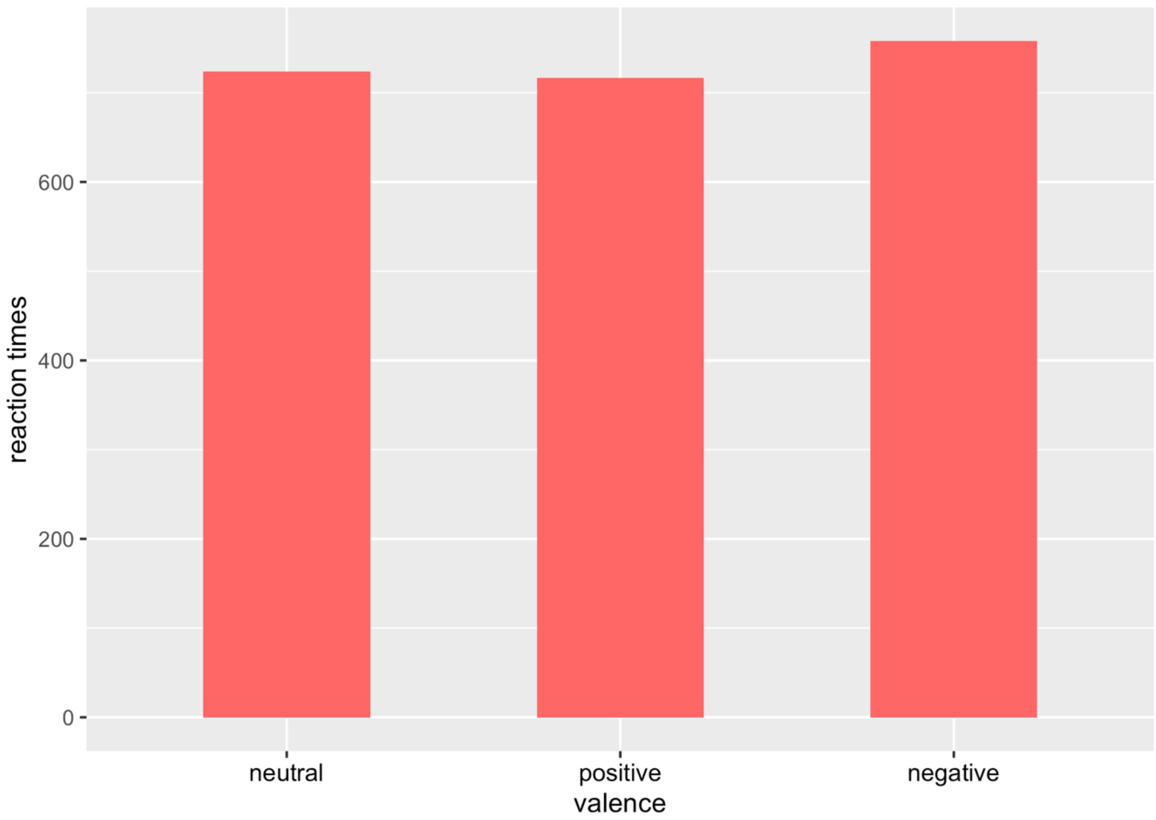
The Effect of Valence on RTs

The analysis examining the main effect of valence on reaction times revealed significant differences between certain valence categories. Reaction times for neutral items were significantly faster compared to negative items, with an estimated difference of 31.41 ms (SE = 8.25, $t(3981) = -3.808$, $p = 0.0004$). Additionally, positive items elicited significantly faster reaction times compared to negative items, with an estimated difference of 36.70 ms (SE = 8.19, $t(3961) = -4.480$, $p < .0001$). However, no significant difference was found between neutral and positive items (estimate = 5.29, SE = 8.19, $t(3984) = 0.646$, $p = 0.7946$). These results are visualised in Figure 2, which shows how close the reaction times for positive and neutral items were.

These findings indicate that positive valence is associated with the fastest reaction times, followed by neutral valence, while negative valence is associated with the slowest reaction times. This pattern underscores the influence of emotional valence on lexical processing speed.

Figure 2

Reaction Times Across Valence Levels

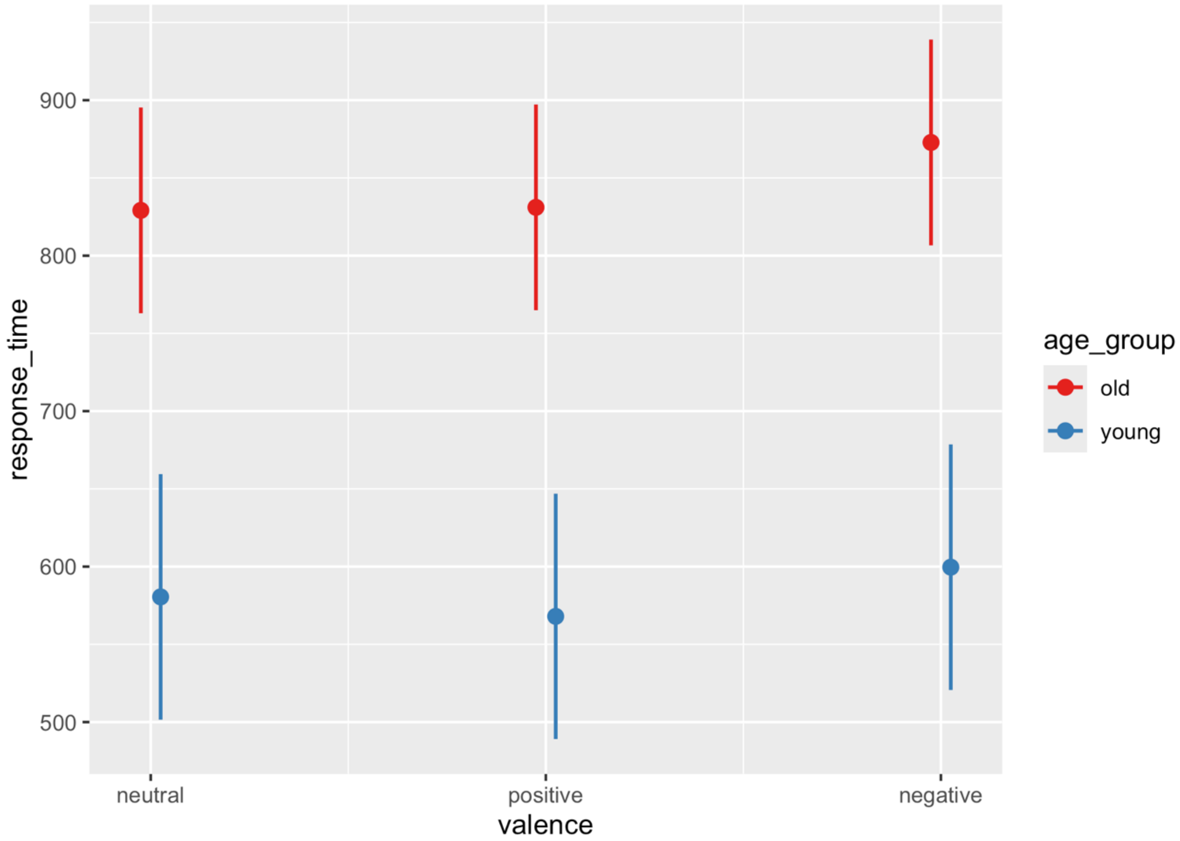


The Interaction Effect of Valence and Age on RTs

The analysis revealed a significant interaction between age group and valence on reaction times. Simple effects analysis of valence indicated that for older adults, positive (p = 0.0002) and neutral (p = 0.0001) items elicited significantly faster reaction times compared to negative items, while neutral items did not differ significantly from positive items. For younger adults, the difference between positive and negative items was smaller but still significant (p = 0.0324). Additionally, simple effects analysis of age group showed that older adults were slower overall compared to younger adults across all valence categories ($p < .0001$). Figure 3 illustrates these differences in reaction times across the two age groups for each valence category.

Figure 3

Response Times for Valence Level within Age Group



The Effect of Language Entropy on RTs

The analysis of the main effect of language entropy scores on reaction times did not reveal any significant differences between the three entropy groups (low, medium, high). Specifically, the contrasts between low and medium entropy scores (estimate = −35.8, SE = 63.5, $t(40) = -0.563$, p = 0.8402), low and high entropy scores (estimate = −72.5, SE = 63.5, $t(40) = -1.141$, p = 0.4952), and medium and high entropy scores (estimate = −36.7, SE = 62.2, $t(40) = -0.589$, p = 0.8266) were all non-significant. This has been put into context in Table 3 where each language entropy group is summarised; special focus for this section is on the mean reaction times for each entropy group, which show only small differences. It also displays that especially in the low entropy group there were twice as many older participants as young participants (11 old vs. 5 young). This would lead to an expectation of a higher mean reaction time for this group than what is actually the case.

These results suggest that entropy, as operationalized by the categorisation of low, medium, and high scores, does not appear to significantly influence reaction times in this dataset. This finding may indicate that variability in language use, as measured by entropy, does not exert a strong direct effect on lexical decision processing.

Table 3

Overview of Language Entropy Groups

Age Group	Low Entropy	Medium Entropy	High Entropy
Young	5	7	7
Old	11	8	8
Total	16	15	15
Mean Age	55	49	48
Response Times	711.21	726.65	761.78

Note. Mean age for each entropy group in years. Response Times are the mean reaction times of each entropy group, rounded to two decimals.

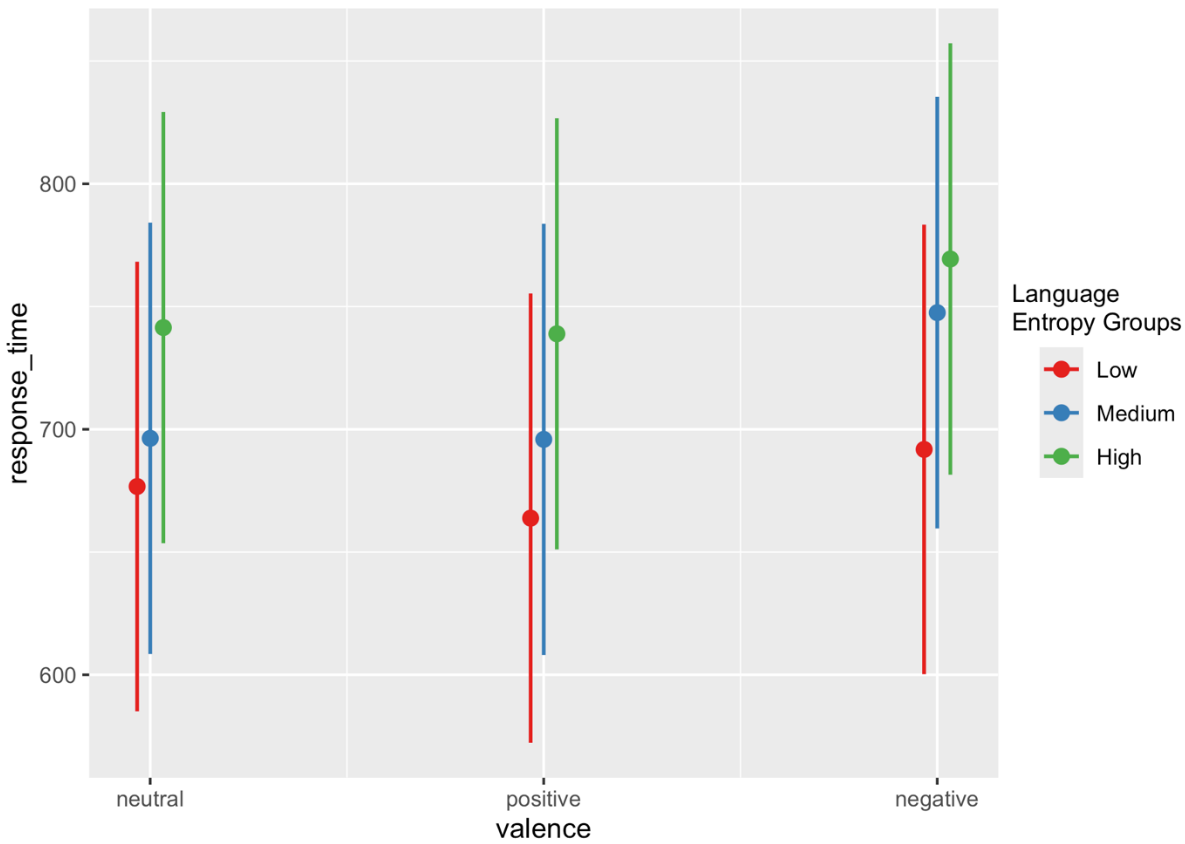
The Interaction Effect of Language Entropy and Valence on RTs

The analysis examining the interaction between emotional valence and bilingual language entropy scores revealed some interesting patterns in reaction time differences.

No significant simple effect of language entropy within valence was found. However, the visualisation in Figure 4 of the results does show that the low entropy group had faster reaction times across all valence categories as compared to the medium and high entropy groups. The high scores, in turn, show the slowest response times across all valence categories. While the differences within each valence category might not have been statistically significant, the visualisation does indicate a response time pattern across the categories.

Figure 4

Reaction Times for Language Entropy Scores within Valence Categories



The analysis of valence within language entropy groups revealed differences in the influence of valence on reaction times across levels of bilingual language entropy. Significant results were observed primarily in the medium entropy group. Specifically, neutral items elicited significantly faster reaction times compared to negative items ($p = 0.0008$), and positive items were significantly faster than negative items ($p = 0.0007$). In contrast, no significant differences were observed in the low and high entropy groups.

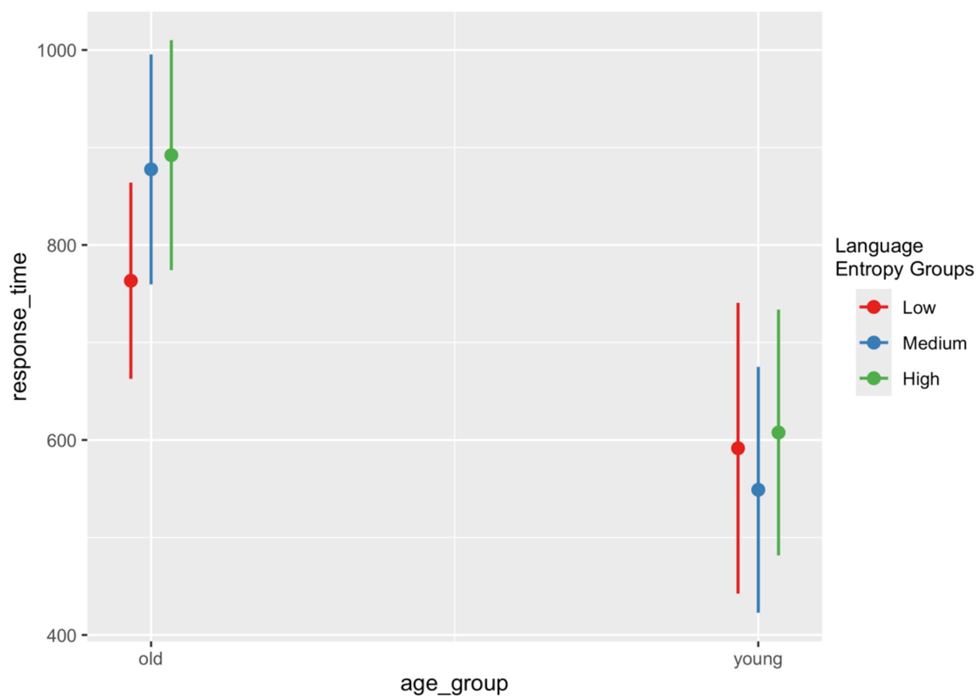
The Interaction Effect of Language Entropy and Age on RTs

The analysis examined the influence of bilingual language entropy on reaction times across the two age groups (old vs. young). Simple effects analysis of language entropy within age group indicated that for older adults there were no significant differences in reaction times between the entropy groups. Specifically, the contrasts between low and medium (estimate = -114.2, SE = 79.0, $p = 0.3275$), low and high (estimate = -128.8, SE = 79.0, $p = 0.2446$), and medium and high (estimate = -14.6, SE = 85.0, $p = 0.9839$) were not statistically significant. This suggests that in older adults, reaction times were not influenced by the level of bilingual language entropy.

Similarly, no significant differences were observed between entropy groups for the younger adults. The contrasts between low and medium (estimate = 42.6, SE = 99.5, $p = 0.9042$), low and high (estimate = -16.1, SE = 99.5, $p = 0.9857$), and medium and high (estimate = -58.7, SE = 90.9, $p = 0.7956$) did not yield significant results, indicating that language entropy did not significantly impact the reaction times of younger adults, which is also illustrated in Figure 5.

Figure 5

Reaction Times for Language Entropy Scores within Age Groups



Discussion

This study aimed to establish the influence of being bilingual on the processing of emotion words in the first language of both younger and older adults by using a lexical decision task. We hypothesised positive items would have the fastest reaction times compared to neutral and negative items. Further we expected older participants to show slower reaction times than younger participants. When combining those two hypotheses, we expected both participant groups to show the fastest reaction times for positive items and the slowest for neutral items. However, older participants were expected to show a bigger positivity effect than the younger group. We further hypothesised participants with high entropy scores would have faster reaction than those with low scores. For combining entropy with valence, we still expected all three groups to show the fastest reaction times to positive items and the slowest for neutral items. However, we also expected participants with higher scores to show faster responses to positive items than participants with lower scores. Lastly, we hypothesised old participants with high entropy scores would show faster response times than those with low scores. It was hypothesised that young participants with low scores might be closer to old participants with high scores in their reaction times.

The results for the first hypothesis, valence, are as expected and in line with former research, namely positive items were responded to the fastest (Kazanas & Altarriba, 2015; Crossfield & Damian, 2021), whereas participants took significantly longer to respond to negative items. These results were to be expected and are corroborating findings to the literature on emotion word processing, and especially the positivity bias, discussed in the introduction (Charles et al., 2003). These results are in line with a part of our first hypothesis about valence. Reaction times to neutral items did not differ significantly from positive items, which was not expected by us as we hypothesised that neutral items would be slowest. A possible reason for this could be that the range from which they were selected might have been more on the positive side of the spectrum than directly in the middle.

We also found a significant main effect for age on reaction times in the lexical decision task. Older participants reacted significantly slower to the stimuli than the younger participants. This result is in line with our hypothesis and is a corroborating finding to the literature on age-related differences in reaction times (Mill et al., 2009), showing that generally reaction times increase as people get older.

The results for our hypothesis on the interaction of valence and age group showed a clear positivity effect for both age groups. Even though the contrast between positive and negative items was significant for the younger adults, it was smaller in magnitude than in the older adults. This showed a bigger processing advantage of positive items for the older adults, which is in line with former research on age-related processing differences (Kensinger, 2008; Ponari et al., 2015). Negative items showed the slowest reaction times for both age groups. However, while older adults showed a significant difference between neutral and negative items, younger adults did not show such a significant difference. This could be due to younger adults interpreting the neutral items as more neutral than the older adults, which had very comparable reaction times for positive and neutral stimuli (as discussed above). However, it could also highlight an age-related difference in the processing of negative stimuli, with older adults taking longer to disengage from the negative stimuli and the cognitive interference they caused. These findings highlight subtle differences in emotional processing across the lifespan, contributing to our understanding of emotional regulation and cognitive ageing.

We hypothesised that high entropy scores would present with faster reaction times based on the assumption that participants with higher entropy scores were better at inhibitory control, which would be necessary for the lexical decision task. However, we did not find a main effect of language entropy. Comparisons between the three language entropy groups did not show any significant differences in reaction times. While the mean reaction times for each language entropy group do show that the high entropy group had slower response times than the other two groups (low entropy had the fastest response times; see Table 3), these results did not show any statistical significance. This can, on the one hand, mean that the way one uses their languages on a daily basis (compartmentalised vs. integrated) does not have an effect on the processing speed of their first language. However, on the other hand, it could also be the case the small entropy groups with only 15 to 16 participants were not big enough to show a statistically significant effect.

From the mean reaction times of each entropy group, it seemed that the high entropy group was the slowest. This could be an indication that our hypothesis was wrong and that high scores would have the slowest reaction times, while low scores would have the fastest reaction times. In turn, this could mean that people with a more compartmentalised language use, i.e., people that mostly use their languages in separate contexts and do not switch between them (which would lead to a low entropy score), are better at suppressing their other languages during a monolingual task. People with a more integrated use, i.e., people who switch on a more regular basis, would, therefore, take longer to respond on a monolingual linguistic task as maybe their other languages are more active in the background, and it takes more effort to inhibit them for the length of the task (Green & Abutalebi, 2013).

Our hypothesis that participants with higher scores would be faster irrespective of valence category was refuted, because no simple effect of entropy was found across valence categories. However, through the visualisation we can see, that the high entropy group had the slowest reaction times, whereas the low entropy group showed the fastest reaction times, both irrespective of valence category. These results are in line with the speculation we have just made about people with higher entropy scores maybe taking longer to respond due to it taking more effort to inhibit their other languages for a longer amount of time. However, the lack of statistical significance could suggest that the variation in language entropy does not robustly modify the impact of emotional valence on response times.

A significant positivity effect for every entropy group could not be found. However, what was found was a positivity effect in only the medium entropy group. This was quite unexpected; however, it could suggest that medium entropy may create an optimal level of variability where valence effects on processing are most pronounced. Furthermore, while entropy does not appear to significantly differentiate reaction times for the valence categories, the relationship between entropy and processing speed may be more complex and warrants further exploration.

Our last hypothesis was concerned with the effect language entropy could have on different age groups. While we did find that older participants were overall slower than younger participants, which we did expect, we did not find an effect of language entropy within either age group. Based on our data, it seems that language entropy does not have an age-related effect. Our hypothesis that participants with high entropy scores would show faster response times than those with low entropy scores was also not supported by the data. These findings could indicate that language entropy scores affect different age groups the same way. However, a possible reason for these results could also be the distribution of young and old participants between the different entropy groups. While the medium and high entropy groups have comparable numbers from each age group (each seven young and eight old participants), the low entropy group has only five young participants and 11 old participants. This makes for a very big difference between the statistical power of each age group in an already small sample size of 16. Therefore, the current results cannot be considered strong representations of these age groups.

Conclusion

This study aimed to investigate how the regular use of another language may influence emotion word processing in the first language by using a monolingual lexical decision task in the participants' first language (i.e., Dutch). Through the replication of former research findings, namely finding a general positivity effect and an ageing-related increase in reaction times for older adults, we were able to build a reliable foundation for the research into language entropy as a possible predictor for processing speed in the first language. We were, however, not able to find a significant effect of language entropy and also barely any interactions of it with the other two variables, age and valence.

By replicating key findings, such as the general positivity effect and the age-related increase in reaction times, this study reinforces the robustness of these phenomena in monolingual lexical decision tasks, especially in a Dutch speaking population. This serves to validate prior research and solidify the theoretical foundation for future studies. The absence of significant effects of language entropy on emotion word processing in the first language highlights a need for further refinement of this measure. It suggests that the relationship between language use patterns and cognitive processing may be more complex than previously assumed.

The not found effect of language entropy could be due to the small number of participants in each language entropy group. As mentioned in the discussion, each entropy group had only around 15 participants, which is not much for a statistical analysis. These group consisted of the two age groups, which were almost evenly represented in the medium and high entropy groups, however, not in the low entropy group where there was a big difference in numbers of the old and young participants. This is a big limitation for the analysis as not a lot of predictions can be drawn based on five participants, which was the case for the young participants in the low language entropy group. Future research with bigger participant groups would be needed to gain more conclusive results about possible age differences related to language entropy scores.

Participant numbers were a general limitation of this research project, as the two age groups were also quite uneven and a bit small; 27 older participants and 19 younger participants are not ideal sizes for comparing them on different variables. For future research bigger and even sized participant groups would be needed to reach more definitive results for differences between the age groups.

Based on the hypotheses formulated at the beginning of this project and the chosen analysis method, we had to separate the language entropy scores into groups and could not use the raw scores as a continued variable. We chose to split them in three groups to keep more of the nuance than we would have with only two groups. However, it has to be said that because of this we only had the small language entropy groups. To calculate the general language entropy score, which was used to categorise the participants into the different language entropy groups, we averaged the individual entropy scores over contexts within each subject. Entropy scores are calculated based on the distribution of language use across contexts. However, these scores are inherently relative to the number of languages an individual speaks. For example, a bilingual's score of 2 might reflect perfect balance between two languages, while a trilingual's score of 2 could indicate a more imbalanced distribution. This discrepancy arises because the formula for entropy adjusts for the number of possible languages. This variability means that entropy scores are not absolute indicators of language use balance but are relative to each multilingual's profile.

This discrepancy in scores is also a limitation of this study, as we did not give a clear indication of how many languages a participant was allowed to speak to be eligible besides speaking at least two. Therefore, our participants rank from only speaking two languages to speaking five languages or maybe even more, five was, however, the limit for how many languages could be entered into the questionnaire. The variability that resulted from this cannot go unacknowledged. There are risks in directly comparing entropy scores across multilinguals without accounting for the number of languages each speaks; this can lead to misinterpretation of results, or inadvertently conflating effects related to language balance with those related to the number of languages spoken. We were not able to restrict our eligibility criteria to only people speaking a specific number of languages, because we were already struggling with reaching the number of participants that we did. However, future research using language entropy as a measure of bilingual language use should keep this disparity in mind and maybe interpret results within groups that share the same number of languages spoken instead of across groups.

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Appendix

Appendix A – Stimuli

1. Words

Positive valence items	Neutral valence items	Negative valence items
respect	haven	angst
oprecht	kapper	crisis
eerlijk	kerel	misselijk
knuffel	meester	ontslag
tevreden	voertuig	smerig
vakantie	invloed	stank
uniek	praat	schurk
zomer	stroom	pijnlijk
charmant	motor	jaloers
heerlijk	controle	besmet
gezellig	trein	gemeen
trouw	majoor	virus
gezond	beurt	gekwetst
glimlach	drank	wanhopig
talent	handel	schoft
prachtig	keizer	vergif
positief	minnaar	wreed
gelukkig	verbaasd	verraad
prettig	metro	verslaafd
vrijheid	stuur	crimineel
geluk	rapport	ongeluk
briljant	station	hufter
genie	kudde	slaaf
grappig	robot	rotzak
wonder	draai	smeerlap
super	macht	vijand
humor	proef	duivel
succes	machine	scheiding
plezier	motief	leugenaar
vreugde	geheim	klootzak

2. Non-words

Matched for positive items	Matched for neutral items	Matched for negative items
retpecs	ranen	andts
opbocht	lamper	cliwis
eerbeek	lelel	morzelijk
kluncel	leetter	ontkrad
newreten	veektuig	kwekig
vavonzie	insmeed	flist
upook	prijt	paatlijk
nover	streem	jadaars
clarlant	hotir	bevlet
weerleek	fomwrole	gepaan
vecelzig	slein	bisus
slouw	macier	gethitst
genind	bexus	wasrozig
glimlill	snank	schogt
palept	laldel	vernof
blichtig	keever	sjeed
towitiem	linsaar	verbeed
venuwtig	verlijsd	vervliefd
drottig	letjo	kwirinool
knoeheid	waptort	atteluk
belut	gravian	tukder
plilfant	hastive	spaaf
gepee	rusbo	rouwak
plippig	lowok	fleerbap
lolder	lotijm	gijond
fuger	gewaaf	kuinel
uknor	strub	schuiring
rusfes	vleep	dosgenaar
plepaar	porst	schuch
kwilmde	proom	kroolhak

Appendix B – Language Background Questionnaire

Language Background Questionnaire

Start of Block: Demographics

Wat is jouw naam?

○ Voornaam ____

○ Achternaam ____

- -

Wat is jouw biologische sex?

○ Man

○ Vrouw

○ Anders ____

- -

Hoe oud ben jij?

____

- -

Ben jij links- of rechtshandig?

◯ linkshandig

◯ rechtshandig

End of Block: Demographics

Start of Block: LBQ 1

Noteer alle talen die je beheerst in volgorde van **dominantie/vaardigheid** (de taal die je het best kent eerst):

◯ 1 ____

◯ 2 ____

◯ 3 ____

◯ 4 ____

◯ 5 ____

Noteer alle talen die je beheerst in volgorde waarin je ze geleerd hebt (je moedertaal eerst):

◯ 1 ____

◯ 2 ____

◯ 3 ____

◯ 4 ____

◯ 5 ____

Geef aan hoe vaak je de afgelopen periode gemiddeld met elk van deze talen in aanraking bent gekomen. Doe dit in percentages. Het totaal moet uitkomen op 100%.

${Q4/ChoiceTextEntryValue/1} : _______

${Q4/ChoiceTextEntryValue/2} : _______

${Q4/ChoiceTextEntryValue/3} : _______

${Q4/ChoiceTextEntryValue/4} : _______

${Q4/ChoiceTextEntryValue/5} : _______

Total : ________

Wanneer je een tekst kon kiezen om te lezen in al de jouw bekende talen, hoe vak zou je dan voor een tekst in welke taal kiezen? Neem aan dat de originele tekst niet in een van de jouw bekende talen geschreven ist, dus dat je moet kiezen uit vertalingen. Geef dit aan in percentages. Het totaal moet uitkomen op 100%.

${Q4/ChoiceTextEntryValue/1} : _______

${Q4/ChoiceTextEntryValue/2} : _______

${Q4/ChoiceTextEntryValue/3} : _______

${Q4/ChoiceTextEntryValue/4} : _______

${Q4/ChoiceTextEntryValue/5} : _______

Total : ________

Wanneer je met iemand zou praten die alle talen die jij beheerst even goed beheerst, hoe vaak zou je dan voor welke taal kiezen om een gesprek met deze persoon te voeren? Geef dit aan in percentages. Het totaal moet uitkomen op 100%.

${Q4/ChoiceTextEntryValue/1} : _______

${Q4/ChoiceTextEntryValue/2} : _______

${Q4/ChoiceTextEntryValue/3} : _______

${Q4/ChoiceTextEntryValue/4} : _______

${Q4/ChoiceTextEntryValue/5} : _______

Total : ________

Geef op een schaal van 1-7 aan hoeveel tijd jij de volgende talen/dialecten thuis *actief gebruikt*. (1 = helemaal geen gebruik, 7 = altijd)

	1	2	3	4	5	6	7
${Q4/ChoiceTextEntryValue/1}							
${Q4/ChoiceTextEntryValue/2}							
${Q4/ChoiceTextEntryValue/3}							
${Q4/ChoiceTextEntryValue/4}							
${Q4/ChoiceTextEntryValue/5}							

Geef op een schaal van 1-7 aan hoeveel tijd jij de volgende talen/dialecten *actief gebruikt* op school/universiteit. (1 = helemaal geen gebruik, 7 = altijd)

	1	2	3	4	5	6	7
${Q4/ChoiceTextEntryValue/1}							
${Q4/ChoiceTextEntryValue/2}							
${Q4/ChoiceTextEntryValue/3}							
${Q4/ChoiceTextEntryValue/4}							
${Q4/ChoiceTextEntryValue/5}							

Geef op een schaal van 1-7 aan hoeveel tijd jij de volgende talen/dialecten op het werk *actief gebruikt.* (1 = helemaal geen gebruik, 7 = altijd)

	1	2	3	4	5	6	7
${Q4/ChoiceTextEntryValue/1}							
${Q4/ChoiceTextEntryValue/2}							
${Q4/ChoiceTextEntryValue/3}							
${Q4/ChoiceTextEntryValue/4}							
${Q4/ChoiceTextEntryValue/5}							

Geef op een schaal van 1-7 aan hoe vaak jij de volgende talen/dialecten *actief gebruikt* in sociale omgevingen. (1 = helemaal geen gebruik, 7 = altijd)

	1	2	3	4	5	6	7
${Q4/ChoiceTextEntryValue/1}							
${Q4/ChoiceTextEntryValue/2}							
${Q4/ChoiceTextEntryValue/3}							
${Q4/ChoiceTextEntryValue/4}							
${Q4/ChoiceTextEntryValue/5}							

Vul in bij welke culturele achtergrond(en) jij jezelf vindt horen. (Voorbeelden van mogelijke culturen zijn Nederlands (Western), Marokkaans (Arabisch), Chinees, etc.):

- ○ Cultuur 1 ____
- ○ Cultuur 2 ____
- ○ Cultuur 3 ____
- ○ Cultuur 4 ____
- ○ Cultuur 5 ____

Geef aan in welke mate jij jezelf vereenzelvigt met de culturen die je ingevuld hebt op een schaal van 0 tot 10. (i.e., 0 = geen vereenzelviging, 5 = middelmatige vereenzelviging, 10 = complete vereenzelviging). Vul lege velden aub met 0.

- ○ ${Q9/ChoiceTextEntryValue/1} ____
- ○ ${Q9/ChoiceTextEntryValue/2} ____
- ○ ${Q9/ChoiceTextEntryValue/3} ____
- ○ ${Q9/ChoiceTextEntryValue/4} ____
- ○ ${Q9/ChoiceTextEntryValue/5} ____

Hoeveel jaren opleiding heb je achter de rug sinds de basisschool (vanaf de brugklas)?

____

Geef aan wat je hoogst behaalde afgeronde opleidingsniveau is:

- ☐ MAVO/MBO
- ☐ HAVO
- ☐ VWO
- ☐ Gymnasium
- ☐ MBO
- ☐ HBO
- ☐ WO/Bachelor/Master
- ☐ Ph.D.
- ☐ Anders, namelijk: ____

Vul deze vraag in indien je niet altijd in Nederland gewoond hebt. Wanneer ben je naar Nederland geëmigreerd?

____

Vul deze vraag in als je ooit naar een *ander* land bent geëmigreerd. Welk land was dit en van wanneer tot wanneer heb je daar gewoond?

____

Heb je ooit met een van de volgende zaken te maken gehad: (Vink aub aan wat op jou van toepassing is.) Zo ja, geef dan aub een korte uitleg.

- ☐ problemen met je zicht

  ____

- ☐ problemen met je gehoor

  ____

- ☐ taalachterstand ____

- ☐ leerachterstand ____

End of Block: LBQ 1

Start of Block: LBQ 2

De volgende vragen gaan over jouw kennis van het ${lm://Field/1}.

Dit is mijn ... taal.

- ○ moeder
- ○ tweede
- ○ derde
- ○ vierde
- ○ vijfde

Wat is de leeftijd waarop je:

- ○ ${lm://Field/1} begon te leren ____
- ○ bekwaam begon te worden in het ${lm://Field/1} ____
- ○ begon te lezen in het ${lm://Field/1} ____
- ○ bekwaam begon te worden in het lezen van het ${lm://Field/1} ____

Geef aub de tijd aan die je in deze taalomgeving hebt doorgebracht in jaren en maanden:

◯ Een land waar ${lm://Field/1} wordt gesproken

____

◯ Een familie waar ${lm://Field/1} wordt gesproken

____

◯ Een school/werkomgeving waar ${lm://Field/1} wordt gesproken

____

Geef je niveau van **bekwaamheid** in spreken het ${lm://Field/1} aan op een schaal von 1 tot 10:

- 0 - geen
- 1 - zeer laag
- 2 - laag
- 3 - redelijk
- 4 - bijna voldoende
- 5 - voldoende
- 6 - ruim voldoende
- 7 - goed
- 8 - zeer goed
- 9 - uitstekend
- 10 - perfect

Geef je niveau van **bekwaamheid** in begrijpen van gesproken ${lm://Field/1} aan op een schaal von 1 tot 10:

- ◯ 0 - geen
- ◯ 1 - zeer laag
- ◯ 2 - laag
- ◯ 3 - redelijk
- ◯ 4 - bijna voldoende
- ◯ 5 - voldoende
- ◯ 6 - ruim voldoende
- ◯ 7 - goed
- ◯ 8 - zeer goed
- ◯ 9 - uitstekend
- ◯ 10 - perfect

Geef je niveau van **bekwaamheid** in lezen het ${lm://Field/1} aan op een schaal von 1 tot 10:

- 0 - geen
- 1 - zeer laag
- 2 - laag
- 3 - redelijk
- 4 - bijna voldoende
- 5 - voldoende
- 6 - ruim voldoende
- 7 - goed
- 8 - zeer goed
- 9 - uitstekend
- 10 - perfect

Geef aan in hoeverre de volgende factoren van **invloed** zijn geweest op het leren van het ${lm://Field/1} op een schaal van 1 tot 10:

	geen invloed	middelmatige invloed	belangrijkste invloed
	0 1 2 3	4 5 6 7	8 9 10
Interactie met vrienden			
Interactie met familie			
Lezen			
Opleiding/Zelfinstructie			
Televisie kijken			
Radio/Muziek luisteren			

Geef aan in hoeverre je de afgelopen periode in aanraking bent geweest met het ${lm://Field/1} in de volgende situaties:

	nooit	de helft van de tijd	altijd
	0 1 2 3	4 5 6 7	8 9 10
Interactie met vrienden			
Interactie met familie			
Lezen			
Opleiding/Zelfinstructie			
Televisie kijken			
Radio/Muziek luisteren			

In hoeverre denk je dat je zelf een buitenlands accent hebt in het ${lm://Field/1}?

- ◯ 0 - geen
- ◯ 1 - bijna geen
- ◯ 2 - heel weinig
- ◯ 3 - weinig
- ◯ 4 - een beetje
- ◯ 5 - gemiddeld
- ◯ 6 - aanzienlijk
- ◯ 7 - redelijk zwaar
- ◯ 8 - erg zwaar
- ◯ 9 - extreem zwaar
- ◯ 10 - indringend

Hoe vaak schatten anderen jou in als een niet moedertaalspreker van het ${lm://Field/1} op basis van je accent?

- ◯ 0 - nooit
- ◯ 1 - bijna nooit
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 - de helft van de tijd
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10 - altijd

End of Block: LBQ 2

Start of Block: Switching

Wissel jij tussen jouw talen/dialecten als je spreekt?

- ◯ Nee, ik gebruik mijn talen/dialecten voor verschillende situaties (bijvoorbeeld één taal thuis en andere buitenshuis, of één taal met bepaalde mensen en andere talen met andere mensen).
- ◯ Ja, ik wissel tussen talen binnen één situatie of gesprek, meestal per zin.
- ◯ Ja, ik wissel tussen talen binnen één situatie of gesprek, meestal woord voor woord.

Geef op een schaal van 1-5 aan hoe vaak jij binnen één gesprek wisselt tussen meerdere talen (code-switching) met de volgende mensen. (1 = nooit, 5 = altijd)

niet toepasbaar

	1	2	3	4	5
familie					
vrienden					
collega's					
medecursisten					
huisgenoten					
partner					

Geef op een schaal van 1-5 aan hoe vaak jij wisselt tussen meerdere talen binnen de volgende situaties. (1 = nooit, 5 = altijd)

niet toepasbaar

	1 2 3 4 5
thuis	
op school/universiteit	
op het werk	
sociale activiteiten (bijv. vrienden ontmoeten, bioscoopbezoek)	
religieuze activiteiten	
activiteiten in de vrije tijd (bijv. hobby's, sport)	
winkelen/restaurants/andere commerciële diensten	
gezondheidszorg/overheid/overheidsdiensten/banken	
online (bijv. op sociale media)	

End of Block: Switching

Appendix C – Tables from the Statistical Analysis

Hypothesis 1 – Valence

Table 4

Results of the Emmeans Analysis for the Main Effect of Valence

Contrast	Estimate	SE	df	*t* ratio	*p* value
Neutral – Positive	5.29	8.19	3984	0.646	0.7946
Neutral – Negative	-31.41	8.25	3981	-3.808	**0.0004**
Positive - Negative	-36.70	8.19	3961	-4.480	**<.0001**

Note. Significant p values ($p < 0.05$) have been indicated in bold.

Hypothesis 2 - Age

Table 5

Results of the Emmeans Analysis for the Main Effect of Age Group

Contrast	Estimate	SE	df	*t* ratio	*p* value
Old - Young	262	51.5	40	5.078	**<.0001**

Note. Significant p values ($p < 0.05$) have been indicated in bold.

Hypothesis 3 – Valence and Age

Table 6

Results of the Emmeans Analysis for the Simple Effect of Valence Category within Age Group

Age Group	Contrast	Estimate	SE	df	*t* ratio	*p* value
Old	Neutral - Positive	-1.94	10.4	3975	-0.186	0.9811
	Neutral - Negative	-43.70	10.5	3956	-4.179	**0.0001**
	Positive - Negative	-41.76	10.6	3953	-3.996	**0.0002**
Young	Neutral - Positive	12.53	12.6	3968	0.996	0.5792
	Neutral - Negative	-19.11	12.7	3967	-1.506	0.2882
	Positive - Negative	-31.64	12.6	3954	-2.511	**0.0324**

Note. Significant p values ($p < 0.05$) have been indicated in bold.

Hypothesis 4 – Language Entropy

Table 7

Results of the Emmeans Analysis for the Main Effect of Language Entropy

Contrast	Estimate	SE	df	*t* ratio	*p* value
Low – Medium	-35.8	63.5	40	-0.563	0.8402
Low – High	-72.5	63.5	40	-1.141	0.4952
Medium - High	-36.7	62.2	40	-0.589	0.8266

Hypothesis 5 – Language Entropy and Valence

Table 8

Results of the Emmeans Analysis for the Simple Effect of Language Entropy within Valence Categories

Valence	Contrast	Estimate	SE	df	*t* ratio	*p* value
Neutral	Low – Medium	-19.6	64.6	42.7	-0.304	0.9505
	Low – High	-64.7	64.6	42.7	-1.002	0.5795
	Medium - High	-45.1	63.2	42.7	-0.713	0.7570
Positive	Low – Medium	-32.1	64.6	42.7	-0.497	0.8733
	Low – High	-75.1	64.6	42.7	-1.163	0.4815
	Medium - High	-43.0	63.2	42.7	-0.680	0.7761
Negative	Low – Medium	-55.7	64.6	42.8	-0.863	0.6668
	Low – High	-77.6	64.6	42.8	-1.201	0.4593
	Medium - High	-21.9	63.3	42.8	-0.345	0.9364

Table 9

Results of the Emmeans Analysis for the Simple Effect of Valence Categories within Language Entropy Group

Language Entropy	Contrast	Estimate	SE	df	*t* ratio	*p* value
	Neutral - Positive	12.891	14.5	3947	0.888	0.6482
Low	Neutral - Negative	-15.099	14.6	3955	-1.033	0.5560
	Positive - Negative	-27.990	14.5	3929	-1.929	0.1306
	Neutral - Positive	0.447	14.0	3968	0.032	0.9994
Medium	Neutral - Negative	-51.189	14.1	3973	-3.630	**0.0008**
	Positive - Negative	-51.637	14.0	3955	-3.682	**0.0007**
	Neutral - Positive	2.543	13.9	3972	0.183	0.9818
High	Neutral - Negative	-27.929	14.0	3953	-1.997	0.1130
	Positive - Negative	-30.471	13.9	3944	-2.185	0.0738

Note. Significant p values ($p < 0.05$) have been indicated in bold.

Hypothesis 6 – Language Entropy and Age

Table 10

Results of the Emmeans Analysis for the Simple Effect of Language Entropy within Age Group

Valence	Contrast	Estimate	SE	df	*t* ratio	*p* value
	Low – Medium	-114.2	79.0	40	-1.446	0.3275
Old	Low – High	-128.8	79.0	40	-1.631	0.2446
	Medium - High	-14.6	85.0	40	-0.172	0.9839
	Low – Medium	42.6	99.0	40	0.428	0.9042
Young	Low – High	-16.1	99.5	40	-0.162	0.9857
	Medium - High	-58.7	90.0	40	-0.646	0.7956