UNIVERSITA' VITA-SALUTE SAN RAFFAELE

CORSO DI DOTTORATO DI RICERCA IN NEUROSCIENZE COGNITIVE

CONSTRUCTING THE RELATIONSHIP BETWEEN LANGUAGE AND EMOTION: EVIDENCE FROM MONOLINGUAL AND BILINGUAL SPEAKERS

DoS: Prof. Jubin Abutalebi

Tesi di DOTTORATO di RICERCA di Camilla Bellini

matr. 019548

Ciclo di dottorato XXXVII

SSD M-PSI/02

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All the results presented here were obtained by myself, except for:

1) *Behavioral analyses (Experiment 1, Chapter 5.1.6)*
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2) *Behavioral analyses (Experiment 2, Chapter 5.2.6.1, Figure 4)*
   were performed in collaboration with Dr. G Del Mauro, Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, USA.

3) *fMRI analyses (Experiment 2, Chapter 5.2.6.2, Figure 5)*
   were performed in collaboration with Dr. G Del Mauro, Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, USA.

4) *Behavioral analyses (Experiment 4, Chapter 5.4.5, Figures 10-13)*
   were performed by Dr. G Del Mauro, Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, USA.

All sources of information are acknowledged by means of reference.

I am co-author of the following manuscripts:

1) Abutalebi J, Bellini C, Gallo F, Del Maschio N (in press) Brain and bilingualism. In *Encyclopedia of the Human Brain* (2nd Edition), Binder JR (Eds.). Elsevier.
   I contributed to the chapter by writing the paragraph "*Bilingualism and decision-making*", reviewing and editing the entire work.

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ABSTRACT

A growing body of evidence shows that emotional stimuli tend to be perceived as having a different impact depending on whether they are processed in one's mother tongue or in a foreign language. According to constructionist theories of emotion, such language-related differences in the perception and experience of emotions arise from the fact that language provides the context for the construction of emotion. Language is thought to interpret sensations in terms of discrete emotions through the words stored in conceptual knowledge. Languages that encode different emotion words would thus differ with respect to what is perceived as an emotion and how it is experienced. Experiencing emotions differently according to the language of processing should also have a relevant impact on cognition and behavior, including decision-making. Indeed, making choices in a first vs. second language has been shown to lead to decision outcomes that are systematically different. The present dissertation aims to provide additional evidence of the role of language in emotion perception and experience. Findings from both monolingual and bilingual speakers support the claim that language is a necessary ingredient in the construction of emotions, as it supports the development and organization of conceptual knowledge which is accessed to make emotions meaningful. Accordingly, our results show that such access is triggered to a greater extent by stimuli presented in the first vs. second language, leading to a deeper and more intense emotional resonance. Nevertheless, a higher proficiency in the second language seems to induce a native-like access to conceptual knowledge and, thus, emotional experience. Moreover, findings indicate that language-related differences in decision-making, when present, are mediated not by a different emotionality but by a different access to the social concepts encoded in conceptual knowledge. Yet individual differences in bilingual language background seem to significantly affect decisions and judgments, above and beyond the simple effect of the language of processing. Therefore, the current dissertation provides original findings that contribute to our understanding of the dynamic interplay between language and emotion, also revealing insightful bilingualism-related effects on this relationship.

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ACRONYMS AND ABBREVIATIONS

ACC: Anterior Cingulate Cortex.

AoA: Age of Acquisition.

CC: Certain Condition.

CERMAC: Centro Eccellenza di Risonanza Magnetica ad Alto Campo.

CP: Categorical Perception.

CRT: Cognitive Reflection Test.

dlPFC: Dorsolateral Prefrontal Cortex.

DMN: Default Mode Network.

EEG: Electroencephalogram.

EI: Emotional Intelligence.

ELA: English Language Assessment.

EPI: Echo Planar Imaging.

EPN: Early Posterior Negativity.

EPT: English Proficiency Test.

ERP: Event Related Potential.

EST: Emotional Stroop Task.

EW: Emotional Word.

FA: Flip Angle.

FWE: Family-Wise Error.

FLE: Foreign Language Effect.

fMRI: Functional Magnetic Resonance Imaging.

FOV: Field of View.

FWHM: Full Width at Half-Maximum.

GLM: General Linear Model.

HRF: Haemodynamic Response Function.

IOG: Inferior Occipital Gyrus.

ITG: Inferior Temporal Gyrus.

L1: First Language.

L2: Second Language.

LDT: Lexical Decision Task.

LHQ3: Language History Questionnaire (Version 3).

LPC: Late Posterior Component.

LRT: Likelihood Ratio Test.

Lx: Foreign Language.

MNI: Montréal Neurological Institute.

mOFC: Medial Aspects Of The Orbitofrontal Cortex.

MOG: Middle Occipital Gyrus.

MPRAGE: Magnetization Prepared Rapid Gradient Echo.

MRI: Magnetic Resonance Imaging.

MTG: Middle Temporal Gyrus.

NW: Neutral Word.

PCA: Principal Component Analysis.

PCC: Posterior Cingulate Cortex.

PE: Phase Encoding Direction.

PEV: Productive Emotion Vocabulary Test.

PID-5: Personality Inventory for DSM 5.

PreCG: Precentral Gyrus.

PSE: Point Of Subjective Equivalence.

PVT: Productive General Vocabulary Test.

ROI: Region Of Interest.

RT: Reaction Time.

RVT: Receptive General Vocabulary Test.

SOG: Superior Occipital Gyrus.

SPL: Superior Parietal Lobe.

SPM: Statistical Parametrical Mapping.

Std. Err.: Standard Error.

STG: Superior Temporal Gyrus.

TE: Echo Time.

TEIQue-SF: Trait Emotional Intelligence Questionnaire – Short Form.

TR: Repetition Time.

UC: Uncertain Condition.

VET: Vocabulary Of Emotion Test.

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Table A20. Experimental stimuli (Experiment 3).

1 INTRODUCTION

Both language and emotions are fundamental aspects of human life, especially with regard to social life as they allow us to connect with others. At first glance, these two dimensions of human cognition seem to be distinct. Yet growing evidence suggests that language does not merely label emotion but instead plays an active role in constructing emotional perceptions and experiences. Indeed, in a constructionist perspective of emotions, language is thought to support the development and retrieval of emotion conceptual knowledge, that refers to what people know about emotions. In particular, it has been suggested that words serve to promote the acquisition of emotion categories by grouping together different instances that share some common features. Accordingly, languages encoding different emotion words would show even slight differences in how they conceptualize and experience emotions. This issue is relevant nowadays, as the majority of people speak and use more than one language on a daily basis. Indeed, it is a common experience to feel different, as having slightly different personalities, when reporting an emotional event in a later acquired language. Try to think of having to tell your partner that you love them. If your first language is Italian, saying “ti amo” will feel more natural and authentic than “I love you”, “je t’aime” or “Ich liebe dich”. Building on this initial subjective evidence, many studies have used more objective techniques to investigate whether bilinguals do, in fact, exhibit differences in responsiveness to emotional stimuli when presented in a second versus a first language. Additionally, as our perceptions and experiences shape our subsequent behavior, decisions can be made differently depending on the language in use. A widely reported finding in the domain of decision-making is indeed that people make more rational choices when using a second as compared to the first language. This dissertation thus aims to provide new insights on the relationship between language and emotion in both monolingual and bilingual speakers. Firstly, it will be investigated whether a wider vocabulary, standing for a broader conceptual knowledge, corresponds to a better accuracy in perceiving emotion from faces in a sample of monolingual speakers. Then, bilinguals’ emotionality in their two languages will be explored, assessing whether and to what extent they recruit the same neural resources to process emotional stimuli. Finally, it will be tested whether bilingual speakers make different choices and judgments in their languages.

1.1 OUTLINE OF THE MANUSCRIPT

The present dissertation provides experimental evidence of the role of language in constructing emotions, in both monolingual and bilingual speakers. The relationship between language and emotion relationship is investigated in five experiments that use behavioral and functional magnetic resonance imaging (fMRI) methods. Experiment 1 examines, in a sample of monolingual speakers, whether a larger vocabulary size (a proxy for conceptual knowledge) is associated with a sharper categorical perception of emotion from faces. Experiment 2 and Experiment 3 extend the scope of the present investigation to bilingualism, assessing whether bilinguals experience emotions differently in their two languages, and whether such experience is underpinned by different neural substrates. Experiment 4 and Experiment 5 explore whether bilinguals' decisions and judgments are modulated by the language context (first vs. second) in which they are made.

The manuscript is organized as follows.

Chapter 1 introduces the thesis' rationale against the background of the relevant literature. *Section 1.1* briefly outlines the structure of the present dissertation. In *section 1.2* an overview is offered of the conceptualization of the relationship between language and emotion within the main psychological theories of emotion. *Section 1.3* focuses on the psychological constructionist theory of emotion, which proposes language as the context for the construction of emotions, detailing its assumptions and supportive findings. *Section 1.4* describes whether bilinguals' emotional life changes according to the language in which stimuli are processed and experienced, reviewing both behavioral and neuroimaging evidence of emotional processing across a bilingual's two languages. Finally, *section 1.5* illustrates how bilinguals' choices and judgments can be affected by the language used, presenting both the behavioral and neuroimaging literature on the topic. The five experiments included in the dissertation are introduced in *sections 1.6, 1.7, 1.8, 1.9 and 1.10*. Of note, Experiment 2, Experiment 3 and Experiment 4 have been already published in peer-reviewed journals, yet with a slightly different structure and wording (Del Maschio et al., 2024; Bellini et al., 2024; Del Maschio et al., 2022b, respectively). Experiment 1 (in preparation) will be shortly submitted to a peer-reviewed journal. Experiment 5 is currently under review.

Chapter 2 Aim of the work briefly summarizes the objectives of the experiments included in the present dissertation.

Chapter 3 Results provides the findings of the reported experiments. The chapter is divided into five sections, one for each study.

Chapter 4 Discussion comprises a discussion of the results of each experiment, followed by a broader discussion that also highlights the specific contribution of the present dissertation and its novelty.

Chapter 5 Materials and Methods describes the materials and methodologies adopted in each experiment. The chapter is divided into five sections, one for each experiment.

Chapter 6 References lists the bibliography in alphabetical order.

Chapter 7 Appendices contains the supplementary materials cited throughout the dissertation.

1.2 THE HISTORY OF THE RELATIONSHIP BETWEEN LANGUAGE AND EMOTION IN PSYCHOLOGY

Both emotion and language play a crucial role in human life, shaping our functioning as individuals and in society. Indeed, emotions, when personally experienced or perceived in others, would allow us to interpret the current situation, to infer its antecedents (i.e., what determined it) and its consequences (i.e., what it will determine), and to optimally act on it. Then, the resulting experience can be communicated to others both through words (i.e., linguistic information) and the way they are said and the bodily gestures that accompany them (i.e., paralinguistic information, such as facial expressions). Thus, emotion and language are certainly interrelated: we put into words our feelings when talking with ourselves and others. But what is the nature of the relationship between language and emotion? In this section an overview of the history of the conceptualization of the language-emotion link within the main psychological theories of emotion will be provided.

Common sense would answer that this relationship is unidirectional, thus limiting the role of language in emotion to communicating the experience once it has been generated. Indeed, intuitively, language and emotions have little to do with each other with respect to their representations and processes. In psychology, this commonsense view is embodied within basic emotion theories (e.g., Ekman, 1992; Izard, 1994; for recent reviews, see Ekman & Cordaro, 2011; Izard, 2011). Such views conceive emotions as biological states arising from innate neural mechanisms that trigger specific facial expressions of a limited number of universal emotion categories. Emotion categories are thus processed by universal hardwired neural circuits and, consequently, recognized all over the world. Accordingly, emotions are specifically and consistently coded through certain combinations of facial muscle movements and then easily interpreted by everyone without the use of language. Emotion perception would thus be automatically driven by facial expressions, demanding merely the decoding of the information encoded in a certain facial expression. Therefore, in basic emotion theories language comes into play only to label or externalize emotional events after the fact, once they have been facially expressed (Ekman & Cordaro, 2011). Consistently, emotion categories, such as anger, fear, or joy, are conceptualized as natural kinds (e.g., Izard, 1971; Ekman & Cordaro,

2011), that is categories that exist in nature. According to a natural kind view, emotions are thus real entities, fundamentally distinct from other types of mental states (e.g., perceptions, cognitions), that exist in the human brain and lead to a specific and consistent set of synchronized outcomes (e.g., facial or physiological responses; Allport, 1924; Cannon, 1921) that are thought to be the signature of emotions. As such, the focus has long been on the search for peripheral psychophysiological, facial, vocal and neural signatures of emotions, with some individual studies successfully reporting distinct biobehavioral correlates of discrete emotions. Yet evidence of specific and consistent autonomic, behavioral and neural patterns differentiating each basic emotion failed to systematically emerge (for a review, see Barrett, 2006a).

Despite such conflicting findings, the natural kind approach maintained its popularity during the late 20th century in part due to the concomitant revival of causal appraisal models. According to such models, a cognitive appraisal (e.g., Arnold, 1960; Irons, 1894) or a set of appraisals (e.g., Roseman, 1984, 1991; Scherer, 1984) of the stimulus situation leads to the emergence of a discrete emotion, which in turn triggers a suite of consistent and specific physiological and behavioral responses. As in basic emotion approaches, emotions are conceived as natural kinds as all instances within the same category arise from the same mechanism (i.e., a specific appraisal or set of appraisals). Crucially, conceptualizing appraisal as an intermediate mechanism between the trigger and the emotion allowed the natural kind approach to explain the considerable variability observed in the physiological and behavioral signatures of emotions. Indeed, the same stimulus can be appraised differently from different people, thus leading to different emotions and, hence, outcomes (Roseman, 2011).

Yet, growing evidence shows that emotions are highly variable, questioning their theorized status as real entities triggered by innate neural or cognitive mechanisms and measurable in specific sets of physiological, bodily and behavioral responses (Lindquist, 2013). On the one hand, only weak correlations have been found among the various outputs of each emotion category (Bradley & Lang, 2000; Mauss, Wilhelm & Gross, 2004), challenging the hypothesis that such responses are determined by a single common mechanism (whether neural or cognitive). Yet such outcome measures have been shown to entertain stronger correspondences with the affective dimensions of valence and arousal (Lang et al., 1993). On the other hand, findings suggested that autonomic, bodily

and behavioral measures represent general positively or negatively valenced, low or highly arousing feelings, instead of revealing discrete emotions (e.g., Barrett, 2006a; Cacioppo et al., 2000; Mauss & Robinson, 2009). Furthermore, neuroimaging studies failed to observe a one-to-one correspondence between the perception or experience of a discrete emotion and enhanced activity within a specific brain region or set of brain regions (Lindquist et al., 2012). These findings thus highlight that biological, bodily and behavioral measures can be used to characterize people's affective state in terms of feelings of pleasantness/unpleasantness and activation/calmness, but not as instances of discrete emotions (Barrett, 2006b). As for objective biobehavioral measures, emotion categories seem not to lead to qualitatively different subjective experiences. First, when self-reporting their emotions, people differ with respect to their *emotional granularity* (Barrett, 2004), with some characterizing their experiences in broad, general terms (i.e., low emotional granularity) and others in terms of discrete emotions (i.e., high emotional granularity). Individual differences in such dimension would indicate that not all people distinguish between the emotion categories of anger, sadness and so on, presumably because they do not even know the difference between them (Barrett, 2006b). Second, when projected into a geometric space, self-reported emotional experiences have been shown to assume a circumplex-type shape (for a review, see, for instance, Barrett & Russell, 1999), rather than a simple structure configuration with one factor corresponding to each emotion category. A circumplex configuration is thought to be suggestive of an underlying heterogeneity in emotions, which can be further decomposed into more basic psychological components. Valence (pleasantness/unpleasantness) and arousal (highly activating/poorly activating) have been suggested to represent such primitive components, although the latter to a lesser extent. Indeed, all people can discriminate between a pleasant and an unpleasant affective state, and most of them also between a low and a high activation (Barrett, 2006b).

We effortlessly experience emotions as anger, fear, joy and so on, ourselves and in others' faces in our daily social interactions. As such, we are intuitively led to believe in the existence of innate anger, fear, or joy mechanisms that, when stimulated, trigger the corresponding feeling (of anger, fear, joy, and so on) and biobehavioral responses. Yet, a considerable amount of evidence on subjective experiences and objective biobehavioral

outcomes casts doubt on this belief, framing an emotion paradox (Barrett, 2006b; Barrett, Lindquist & Gendron, 2007).

A solution to such paradox was offered by the new wave of psychological constructionism. Throughout history, psychological constructionist models have emerged as a reaction to natural kind approaches. As early as the 19th century, against Darwin's idea of universal emotions, William James (1890) affirmed that not all instances of an emotion are the same nor their outcomes, being emotions the products of more general causes rather than absolute individual entities. In the same years, Wilhelm Wundt (1897) conceptualized emotions as mental compounds arising from more basic psychological elements, specifically simple feelings on the one hand, and ideation (i.e., a kind of interpretation) on the other hand. Nevertheless, given the limited scientific validity of Wundt's method (i.e., introspection), his claim did not catch on. Later on, in the early 20th century, early constructionist models (e.g., Duffy, 1941; Dunlap, 1932; Harlow & Stagner, 1932) accounted for the considerable variability of emotional events stating that emotions are states suited to a given situation, arising when basic hedonic feelings (Harlow & Stagner, 1932) or feelings of arousal (Duffy, 1941) are made meaningful through cognitive interpretation. Starting from the same purposes, the new wave of psychological constructionism (e.g., Barrett, 2006b; Clore & Ortony, 2008; Lindquist, 2013; Russell, 2003) described the discrete perception and experience of emotion, with whom people are familiar, as emerging from the combination of basic, domain-general psychological ingredients. Yet, unlike previous constructionist approaches, new models founded their hypotheses on neuroscientific evidence and tested them empirically.

All theories within the broader family of psychological constructionism are unified under the assumption that emotions are psychological compounds that result from the combination of more basic elements, and whose properties cannot be reduced to the constitutive elements. Most psychological constructionist accounts hold that such basic psychological elements, not specific to emotions themselves, are interoceptive sensations, exteroceptive sensory inputs, and conceptual knowledge about emotion. Accordingly, an emotion would be perceived in others' faces or personally experienced when emotion conceptual knowledge is used to make meaning of internal body states and external sensations in a given situation. For instance, we experience fear when our sensations of accelerated heartbeat, trembling and sweating (i.e., interoceptions) in front of a

threatening barking dog (i.e., exteroceptions) are made meaningful through our conceptual knowledge about fear.

1.3 A CONSTITUTIVE ROLE FOR LANGUAGE IN EMOTION

Crucially, among constructionist views, the Conceptual Act Theory (Barrett, 2006b; Lindquist, 2013; Lindquist, MacCormack & Shablack, 2015) uniquely emphasize the role of language in constructing emotion, as it funds the development of and access to conceptual knowledge. Within such perspective, the basic constituents of emotions are representations of internal sensations, representations of external sensations, and conceptual knowledge. The first ingredient, known as affect, describes a representation of changes in neurobiological states which can be experienced as pleasant or unpleasant with some degree of arousal. As objects or events can modify an individual's bodily state, although in different ways and to different degrees, these continuous transitory alterations in neurophysiological and somatovisceral state are thought to represent the immediate relationship of the organism with the surrounding environment (Barrett, 2011). In this sense, affect is conceived as a homeostatic barometer that allows the organism to understand the external world and safely navigate it (Barrett & Bliss-Moreau, 2009). The second ingredient, exteroceptive sensations, describes a representation of sensory information coming from outside the body. They contribute not only to the perception of emotions in others (e.g., visual input about another person's facial muscle movements) but also to the subjective experience of emotions leading to changes in affect (e.g., visual input about a threatening barking dog). Moreover, exteroceptive sensations would inform about the physical surrounding context, helping disambiguate the meaning of internal sensations. The third ingredient, emotion conceptual knowledge, refers to all instances defining what people know about each emotion category. For instance, conceptual knowledge about fear may include sensations of tachycardia, shaking and sweating, presence of threatening contexts or objects, an urge to flee or a freezing behavior. Importantly, this conceptual information is not stereotypical of each emotion, but it varies from individual to individual, from culture to culture, and also over time within the same person. Indeed, instances populating emotion conceptual knowledge are thought to be acquired through both instrumental learning and personal experience in episodes. Once

developed, conceptual knowledge provides a priori information driving predictions about new incoming sensations, supporting the interpretation of their meaning and triggering a response to them (Lindquist, MacCormack & Shablack, 2015). Crucially, within a constructionist account, emotion conceptual knowledge is accessed to make meaning of otherwise ambiguous interoceptive and exteroceptive sensations as instances of a specific emotion within a given context. The process transforming sensations into instances of discrete emotion through conceptual knowledge is termed conceptualization (or categorization). The conceptual knowledge employed during conceptualization develops on prior experiences as a collection of various modality-specific memories encoded across all instances of a given category, including their somatovisceral, sensory and motor features (Barrett, 2011). It follows that emotion concepts are embodied being expressed as brain states including activity in sensory and motor neurons (Barrett, 2011). Accordingly, growing evidence shows that emotion conceptual knowledge is made up of sensorimotor simulations of prior sensory experiences and actions (Glenberg & Gallese, 2012; for a review, see Kiefer & Barsalou, 2013). As instances of a given emotion are collected, integrating information across instances, a simulator for that emotion develops, increasing conceptual knowledge for that emotion. Then, when a stimulus within the surrounding context, an action or an intention to describe affect triggers conceptual knowledge about a given emotion, it constitutes a representation of that emotion tailored to the immediate situation (Barrett, 2006b). To give an example, core affect can be categorized as fear in front of a threatening barking dog, before an exam, hearing eerie noises in the middle of the night, walking alone in an unlit street, and so on. In this sense, conceptualization is heavily dependent on the surrounding context, i.e. it is situated (Barrett, 2066b, 2011; Lindquist, MacCormack & Shablack, 2015). Therefore, each emotion concept is represented not as a single script but as a collection of heterogeneous situated conceptualizations, each different from the others, which can be flexibly combined in many different ways to fit the present context. Crucially, it is language through words that aids in clustering those multiple highly variable instances into a single emotion category (Barrett, Lindquist & Gendron, 2007).

1.3.1 Language and emotion conceptual knowledge

The knowledge accessed during conceptualization is thus supported by language, which would thus play a role in the construction of emotions (Barrett, 2006b; Lindquist

& Gendron, 2013; Lindquist et al., 2012). Language is thought to participate in constructing emotion as it, through words, sustains the development and organization of all instances constituting conceptual knowledge about emotions (Lindquist, 2013). Words have been shown to boost the acquisition of all kinds of categories (Lupyan, Rakison, & McClelland, 2007), driving the categorization of novel objects based on their perceptual similarities with objects named the same (Booth & Waxman, 2002; Fulkerson & Waxman, 2007). Yet, contrary to concrete categories (e.g., "cat") that might be characterized by strong perceptual regularities (e.g., cats have four legs, a tail, a pair of whiskers, and their fur can be variously colored) and prototypes (e.g., a Siamese cat or a Siberian cat), emotion categories are thought to consist of populations of conceptual information with few perceptual regularities (Barrett, 2006a) and no strong prototypical example (Barrett, 2014). As highlighted in the previous section, emotion categories group together many heterogeneous instances that share some features, in particular a common goal-based function within a given situation, while differing with respect to other features across contexts (Barrett, Wilson-Mendenhall, & Barsalou, 2015; Hoemann et al., 2019; Lebois et al., 2020). Emotion categories are thus abstract and conceptual classes, whose exemplars are situated and differ greatly in their characteristics (Barrett, Wilson-Mendenhall, & Barsalou, 2015; Wilson-Mendenhall et al., 2011). Emotion words would cluster such a variety of different instances of an emotion category into a single category (e.g., Barrett, 2006b; Lindquist & Gendron, 2013).

1.3.2 Developing emotion conceptual knowledge

Words are thus thought to drive the acquisition of conceptual categories across development. They have indeed been conceptualized as "essence placeholders" (Xu, Cote & Baker, 2005) for children's acquisition of concepts allowing them to learn a category by binding together instances of the same kind according to their commonalities (Lindquist, MacCormack & Shablack, 2015). Thus, words would lead children to learn that different instances belong to the same category allowing them to focus on the characteristic features and overlook the irrelevant ones (Hoemann, Xu & Barrett, 2019). Similarly, emotion words (e.g., "anger", "fear", "joy", and so on) aid the development of specific and multi-dimensional emotional categories that lead children to interpret a variety of feelings, behaviors and situations as instances of discrete emotions (Nook et al., 2017). Crucially, constructionist approaches to emotion assume that infants are born

not with pre-existing knowledge about certain categories (e.g., Izard, 1978; Ekman & Oster, 1979) but with an innate sensitivity to statistical regularities among experiences (Sirois et al., 2008; Xu & Kushnir, 2013). Infants would thus be able to categorize new instances and predict their antecedents, behaviors, and consequences based on statistical regularities derived from prior experience. This ability, known as probabilistic or statistical learning, is a fundamental aspect of human cognition from womb to tomb (Oaksford & Chater, 2009; Carey, 2011; Clark, 2013). Indeed, as early as three months, infants have been shown to start developing categories for natural kinds (e.g., cats, dogs, horses, and so on; Eimas & Miller, 1992) and artifacts (e.g., beds, chairs, tables; Behl-Chadha, 1996), mostly based on visual statistical regularities (e.g., all cats have whiskers). However, abstract categories, such as emotion ones, cannot be acquired only through visual statistical regularities, given the fact that each emotion word refers to multiple heterogeneous instances that are rarely perceptually regular. Language is thought to aid the acquisition of such abstract categories establishing associations between the phonological form of a word and a given concept (Barrett and Lindquist, 2008; Vigliocco et al., 2009; Borghi & Binkofski, 2014). Accordingly, the phonological sound of a word would be used by infants to differentiate between sensations in the environment. Indeed, from 9 months onwards, words help infants discriminating between similar and dissimilar objects. At around one year, words allow infants to make predictions about what type of objects will be presented. Likewise, emotion words promote infants' conceptual acquisition teaching them that perceptually distinct instances are actually members of the same category. It is the human environment, specifically the words used in interactions with parents and caregivers, that mediates this process. Indeed, using the same words to name objects, caregivers enable their children to compare features (Gentner, 2010), letting them to perceive perceptually similar objects as alike by ignoring their less relevant features, and to perceive dissimilar objects as diverse by emphasizing their distinct features, thus drawing category boundaries (Boroditsky, 2007). Similarly, when caregivers use emotion words to describe events involving multimodal (i.e., perceptual, physical and affective) changes, they allow their children to learn that instances with different features can achieve the same goal in a given situation (Barrett, 2017; Barsalou, 1985).

Importantly, acquisition of emotion concepts appears to parallel language development. Contrary to the view of innate emotion categories, children have been systematically shown to initially possess simple valence-based categories and later develop adult-like categories for distinct emotions (Widen, 2013). As linguistic abilities mature, emotion concepts start to be acquired and used to interpret perceived valenced sensations in terms of discrete emotions (Wu et al., 2023). As a consequence, children would shift from a narrow positive vs. negative categorization to a broader fine-grained emotion conceptual knowledge (Shablack & Lindquist, 2019). For instance, under the age of two, when language skills are not yet developed, infants seem able to discriminate facial expressions only in terms of valence. Then, as children begin to use words in interactions, such bi-directional communication with caregivers provide them direct feedback on their situated conceptualizations of their own and other people's affect, thus leading to more defined emotion concepts. Indeed, three- and four-year olds can perceptually discriminate unpleasant faces into more specific emotion categories, whereas two-year olds tend to group together all unpleasant faces (i.e., angry, sad, fearful and disgusted facial expressions) leaving out happy faces. At around seven years of age, children display an adult-like categorization of most faces but disgust (for a review, see Widen & Russell, 2008). Once developed, emotion categories can be used to perceive and experience emotions and to organize an adequate response in a specific situation (Hoemann et al., 2019). Hence, as children acquire emotion words and use them in daily interactions with caregivers, they start to master emotion perception and experience in terms of culturally relevant emotion categories. Indeed, communication with caregivers has been shown to sustain children's development of a complex knowledge about the culturally relevant emotion categories, leading to improved emotion perception and understanding (e.g., Eggum et al., 2011; Nencheva, Tamir, & Lew-Williams, 2023; Rivers et al., 2013); in turn, a better emotion understanding was found to be associated with better relationships with peers and popularity in children as young as 5 years (Dunsmore & Karn, 2004). Parental discourse is thought to vehicle the acquisition of emotion conceptual knowledge introducing emotion concepts (e.g., "she's happy") and aiding children's understanding of the properties of those concepts (e.g., "she's happy because her grandmother went to visit her", or "finding her favorite toy made her happy"). For instance, 18-month-olds whose mothers produced more emotion words produced more

emotion words themselves at 24 months (Dunn et al., 1987). Moreover, greater parental discourse about emotions with children at 36 months old has been shown to predict a better emotion understanding in children at 6 years (Dunn et al., 1991). On the contrary, parents with a poor conceptual knowledge or unable to transmit this knowledge allegedly hinder the development of a complex emotion conceptual knowledge in their children. Indeed, for example, college students' levels of alexithymia were found to entertain a positive correlation with their mothers' retrospectivity difficulty in expressing emotions when their children were young (Fukunishi and Paris, 2001). Moreover, caregivers' beliefs about emotions would influence children's emotional abilities, determining the quality and quantity of parental discourse about emotions on the one hand, and parental reactions to children's emotions on the other hand (Dunsmore & Halberstadt, 1997; Hakim-Larson et al., 2006). Indeed, parents who value emotion highly are more likely to talk about emotions with their children, allowing them to put their developing emotion conceptual knowledge into practice by giving them feedback on their situated conceptualizations about their own and others' affect. This, in turn, would lead children to develop better socioemotional abilities. For instance, it has been shown that 44-month-olds' cognitive and linguistic abilities, the extent to which their mothers used emotion terms and explained them emotions, and the way in which they responded to children's emotions, predict children's abilities to identify facial expressions (Denham et al., 1994). Moreover, children whose mothers valued emotions were shown to have higher social status among their peers (Dunsmore & Karn, 2004).

To sum up, children's acquisition of emotion concepts is supported by the words used in interactions with the human environment. Moreover, parents aid children's development of emotion conceptual knowledge by making themselves situated conceptualizations of the affective states of their children and other people. As children begin to acquire emotion concepts and to label their own feelings, parents give them feedback on the accuracy of their situated conceptualizations. Along development, children's conceptualizations become more automatic, yet honed and complex. Then, an emotion knowledge that is more defined, due to the content transmitted in parental discourses, and automatically accessible, due to the motivation to make situated conceptualizations transmitted by parents, would lead to a greater emotional awareness

and a better understanding of emotions. This would in turn determine successful interpersonal communication and intrapersonal emotion regulation.

1.3.3 Fine-tuning emotion conceptual knowledge

Language continues to influence emotion perception and understanding beyond early childhood. Indeed, throughout adolescence and early adulthood, while language abilities are consolidating, emotion conceptual knowledge keeps expanding and adjusting (Nook et al., 2017, 2020; O' Kearney & Dadds, 2004). For example, in a sample of individuals aged 6 to 25 years, the shift from a valence-based understanding of emotions to a more nuanced differentiation was found to be mediated by verbal knowledge (i.e., vocabulary scores), a finding that the authors interpreted as suggestive of the moderator role of language in increasing emotion understanding across adolescence (Nook et al., 2017). Crucially, even in adulthood words have been shown to support the re-organization of emotion conceptual knowledge by updating existing emotion categories or acquiring novel concepts (Doyle & Lindquist, 2018; Fugate, Gouzoules & Barrett, 2010). In fact, an embodied account of concept knowledge would predict adults to continuously amend and fine-tune their categories according to current perceptual experiences (Schyns et al., 1998; Vigliocco et al., 2009; Barsalou, 2012). Accordingly, words have been shown to aid adults' acquisition of novel visual categories (e.g., Lupyan, Rakison, & McClelland, 2007). Yet, assessing their causal role in novel emotion concept acquisition is more complicated as most healthy adults already have a fairly well-established conceptual knowledge of the emotional categories relevant to their cultures. Nevertheless, Fugate, Gouzoules & Barrett (2010) tested the role of language in emotion perception through a category-learning task in which unfamiliar Chimpanzee affective facial expressions were employed. First, half participants simply viewed those unfamiliar Chimpanzee faces, the other half viewed the same stimuli and learnt to associate them with nonsense words. Then, participants' categorical perception was assessed by means of an identification and a discrimination task in which morphed Chimpanzee faces were used as experimental stimuli. Categorical perception refers to people's ability to perceived stimuli continuously varying along a dimension in terms of discrete categories (see section 1.6, for a detailed description of categorical perception and the tasks used to assess it). Importantly, only participants who learned the association between faces and words displayed categorical perception, a finding that authors interpreted as suggestive of the power of words in

supporting emotion perception. In another study, adults were shown to assimilate new perceptual experiences into existing emotion categories through words (Dylan & Lindquist, 2018). In the learning phase, participants were shown non-stereotypical facial expressions of anger and fear: half participants learnt to associate them with emotion words (anger or fear), whereas the other half only performed perceptual judgments. Then, in a target phase, participants were asked to categorize stereotypical facial expressions as angry or fearful. Finally, in the test phase, participants had to identify which face (i.e., the learnt one, the target one, or a combination of them) the target individual was making during the target face. Crucially, participants that learnt to associate non-stereotypical faces with emotion words in the learning phase were more likely to remember seeing a target face similar to the learned category information. The authors interpreted their findings as evidence of the role of language in assimilating novel instances into previous categories. As such, language would support not only the development of emotion conceptual knowledge but also its use and access to make meaning of internal and external sensations as instances of specific emotions. Indeed, the emotion concepts activated in a given situation would actively come into play during the perceptual processing itself to construct an emotional perception or experience (Barrett, 2017). Accordingly, emotion conceptual knowledge is thought to shape the ongoing construction of an emotion (Barrett, 2011). Considerable evidence supporting the constitutive role of words in emotion perception arises from typical emotion perception studies, in which participants are required to match posed facial expressions to emotion labels (i.e., anger, disgust, fear, happiness, joy, sadness). Indeed, higher accuracy rates between participants in identifying facial expressions are systematically shown when words are used as response options (> 63% versus between 7.5% and 54% in absence of words; for a review, see Lindquist & Gendron, 2013). More importantly, providing labels can lead participants to perceive a facial expression as an instance of an incorrect emotion (e.g., a scowling face can be perceived as disgusted instead of angry when only the emotion term “disgust” is provided; Russell, 1993). These findings would suggest that words facilitate perception not by boosting recognition memory for later emotional instances, but by leading participants to categorically perceived emotions, maximizing between-category differences and minimizing within-category variability. Furthermore, accessibility to emotion concepts would shape not only how people perceive others’ affective states, but

also how they experience their own feelings. For instance, labelling emotions during a stressful mental arithmetic task led participants to show cardiovascular indexes consistent with an experience of threat (Kassam & Mendes, 2013).

1.3.4 Dampening emotion conceptual knowledge

As providing emotion words boosts emotion perception and experience, hampering the availability of emotion concepts obstacles the construction of emotions. Indeed, when participants' access to the meaning of emotion words is temporarily hampered through semantic satiation (Black, 2003), there is a corresponding impairment in emotion perception from faces (e.g., Lindquist et al., 2006; Gendron et al., 2012). According to the authors, such findings would highlight that access to emotion conceptual knowledge is essential to emotion perception. Evidence from lesion studies further supported such claim, as damage in brain regions involved in language and semantic processing have been shown to determine a concomitant impairment in emotion perception and experience. The first evidence came from a case study (Roberson, Davidoff and Braisby, 1999) showing that, following a stroke impairing object knowledge and naming, the patient was no longer able to sort pictures of emotional faces into groups according to discrete emotion categories. More recently, Lindquist and colleagues (2014) explored emotion perception abilities in patients with semantic dementia, a neurodegenerative disease affecting the anterior temporal lobes and leading to a progressive loss of semantic knowledge. When asked to sort emotional faces into groups, patients with semantic dementia roughly created three clusters based on valence (i.e., positive, negative and neutral feelings), whereas healthy age-matched controls' groups approximated the six emotion categories. The authors, thus, concluded that the impossibility to access to emotion concepts hindered patients' ability to perceive discrete emotions, further strengthening the hypothesized constitutive role of language in emotion.

1.3.5 Neuroimaging evidence for the language-emotion link

Recalling neuroimaging evidence contrary to natural kind approaches to emotion (see section 1.2), and lesion evidence in favor of the constitutive role of language in emotion (see section 1.3.4), it seems implausible that each emotion arises from a specialized brain region or circuit (Satpute & Lindquist, 2019). Indeed, studies on emotion perception and experience highlighted enhanced activity within brain areas

involved in more basic psychological processes, thus not unique to emotion (Kober et al., 2008; Lindquist et al., 2012), such as visceromotor control, conceptual knowledge, and executive control. Accordingly, emotions, as well as other mental states, are thought to emerge through dynamic interactions between multiple functional networks (Horikawa et al., 2020; Barrett & Satpute, 2013). As illustrated in section 1.2, constructionist perspectives conceived emotions as rising from the combination of domain-general psychological elements, such as interoceptive and exteroceptive sensations made meaningful as emotional instances through emotion conceptual knowledge. It follows that the construction of emotions does not rely only upon sensory features but also upon current context, previous experiences, and personal relevance (Saarimäki, 2021). As such, for emotions to be constructed, higher-order information processing is required to integrate information across different modalities and processing levels, and multiple domain-general, distributed functional networks need to be recruited (Chikazoe et al., 2014). Indeed, interoceptive sensations have been systematically shown to engage brain areas involved in visceromotor control, such as the central nucleus of the amygdala, the basal ganglia, the periacqueductal gray, and the subgenual anterior cingulate cortex (for a review, see, for instance, Lindquist & Barrett, 2012; for a meta-analysis, see Kober et al., 2008). Moreover, some of these brainstem areas project connections to medial aspects of the orbitofrontal cortex (mOFC), associated with the representation of hedonic valence (Kringelbach & Rolls, 2004), which would thus represent the affective meaning of bodily inputs. Indeed, it has been suggested that in the mOFC, along with ventromedial subdivisions of the prefrontal cortex, predictions about the meaning of affective feelings arise from representations of previous experiences (Shenhav, Barrett, & Bar, 2013). The representation of interoceptive sensations as affective states is supported also by the anterior insula. The ventral aspect of the anterior insula, which is a part of the salience network (Seeley et al., 2007), strongly connects with the dorsal division of the anterior insula, involved in the allocation of attention based on information from the body (Nelson et al., 2010). Thus, the anterior insula is thought to support the use bodily sensations to direct attention and motivate behavior, to ultimately interact with the world in an efficient way. Exteroceptive sensations, on the other hand, have been linked to modal and heteromodal sensory cortices, such as the auditory and the occipital networks, which support the representation of external sensory perceptions. Emotion conceptual

knowledge has been associated with regions within the default mode network (Yeo et al., 2011) and the language network. In fact, growing evidence showed that emotion perception and experience consistently led to enhanced activity in areas within the default mode network which are engaged in re-enacting previous experiences for their use in present (Lindquist, 2013). The default mode network, including dorsal, ventromedial and ventrolateral aspects of prefrontal cortex, the precuneus, the medial temporal lobe (the hippocampus and the entorhinal cortex), the anterior temporal lobe, and the temporo-parietal junction (Kober et al., 2008; Lindquist et al., 2012; Vytal & Hamann, 2010), has been shown to increase its activity in a broad range of self-oriented cognitive activities, among which recalling past experiences, thinking about the future, predicting others' mental states in a given context, and retrieving autobiographic memories, all of which might incidentally trigger emotional reactions. As such, the DMN has been associated with emotion mainly indirectly. Nevertheless, growing neuroimaging evidence attests that the DMN carries representational content for discrete emotions, allowing for their differentiation into specific categories (Fernandino & Binder, 2024; Satpute & Lindquist, 2019). As mentioned in section 1.2, perceiving and experiencing discrete emotions requires the ability to abstract across heterogeneous instances stored within conceptual knowledge in light of the features of the immediate context and previous experiences. Accordingly, the DMN has been thought to play a constitutive role in creating instances of discrete emotions, as its nodes have been shown to support abstraction both in structural and functional findings (e.g., Finlay & Uchiyama, 2015; Spunt et al., 2016). Crucially, it has been reported that some of these regions, in particular the lateral temporal cortex (extending anteriorly to the temporal pole and posteriorly to the parietal cortex), the ventrolateral and dorsomedial subdivisions of the prefrontal cortex, the posterior cingulate cortex and the precuneus, show overlapping activity between emotion and semantics (for a review, see Satpute & Lindquist, 2021). Indeed, brain regions involved in semantic processing have been systematically shown to be activated during the experience of external sensations in terms of discrete emotions (Oosterwijk et al., 2012), but also during the categorization of different emotions, being potentially crucial for emotion differentiation (for a review, see Satpute & Lindquist, 2019). For instance, Brooks and colleagues (2017) meta-analysed 386 neuroimaging studies employing tasks related to emotional processing in which emotion (or more general affective words, such

as “pleasant”) were present versus absent. They found that the presence of emotion words across experiments led to consistent activations in the inferior frontal gyrus, engaged during semantic retrieval (Huang et al., 2012), and in the middle and superior temporal gyri, involved in semantic knowledge representation (Binder et al., 2009). According to the authors, such findings highlighted that emotion words triggered access to semantic knowledge during emotion perceptions and experiences, further supporting the constructionist claim that language aids the construction of emotion. Furthermore, regions within the DMN have been suggested to interact with regions systematically involved in the representation of affective states, such as the amygdala and the insula (Lindquist et al., 2016), during the creation of emotion perceptions and experiences. For instance, Raz and colleagues (2016) found that a greater functional connectivity between the anterior medial prefrontal cortex and temporal poles with limbic structures predicted deeper experiences of discrete emotions. Moreover, Satpute and collaborators (2016) highlighted an increased functional connectivity between the amygdala and ventromedial portions of the prefrontal cortex, also implicated in semantic processing (Binder et al., 2009), during labelling emotions with words.

Although neuroimaging evidence is correlational, the reviewed evidence strengthened the constructionist approaches to emotion in two ways. On the one hand, there are no brain regions or networks specialized in processing each emotion (e.g., a region for “fear”), instead emotion perception and experience lead to enhanced activity with brain regions engaged in domain-general processes, thus not specific to emotion. On the other hand, the perception and experience of discrete emotions involves brain regions that have been systematically associated with semantic processing.

1.3.6 Linguistic relativity of emotion conceptual knowledge

As language provides the context for the construction of emotions through emotion conceptual knowledge, it is not surprising that emotions may assume different perceptual and experiential connotations in translation between languages that encode different emotion terms (Lindquist, 2017). This issue turns to be relevant nowadays, where the majority of people speaks two or more languages in their daily lives. Indeed, there is growing recognition that emotions can vary systematically in their meaning and experience across cultures and languages (e.g., Barrett et al., 2019; Gendron, Crivelli, &

Barrett, 2018; Gendron et al., 2014). For instance, Crivelli and colleagues (2016) tested emotion perception in individuals with considerable cultural isolation from Western world, the Trobrianders of Papua New Guinea. In a first experiment, requiring participants to match emotional faces with emotion terms, social motives, or both, Trobriand adolescents were found to attribute emotions and social motives to emotional faces in lower proportions than Western individuals. Furthermore, gasping faces were consistently matched with the anger label, instead of the predicted fear, and the social motive of threat, rather than the expected social motive of submission. Then, in a second experiment the authors tested whether the attribution of anger and threat to the gasping face was consistent across different methods and participants. Again, Trobrianders consistently selected the gasping face to represent threat. Gendron and collaborators (2014) compared emotion perception from facial expressions between a sample of American participants and a sample of Otji-Herero speakers of the Himba ethnic group. When participants were required to freely sort emotional faces into piles (i.e., without word-anchors), American participants used discrete emotion words or more generally mental states words significantly more than Himba participants, who instead were more likely to label piles with action descriptors (e.g., laughing). When introducing emotion words as response options, both groups were shown to sort emotional faces into distinct groups, yet with some differences. American participants' sorting was aligned to the "universal" pattern, whereas Himba participants' sorting was better accounted for by mental state descriptors (rather than action descriptor as in the free sorting task), consistent with the claim that emotion words prompt categorical perception of emotional faces. Yet, their sorting did not conform the "universal" pattern as much as that of American participants. According to the authors, such findings strengthen evidence attesting that different cultures have different mental representations of emotional instances, in spite of available translations for a given emotion term across cultures (e.g., Boiger et al., 2018; Jack et al., 2012). Such variability in emotion perception and experience cannot be accounted for assuming the basic emotion view of emotions as natural kinds reducible to innate neural mechanisms. Of course, genetics provide all cultures with some similar biologically evolved mechanisms, such as representation of interoceptive sensations. Indeed, brain regions engaged in visceromotor control (see section 1.3.5) are consistently involved during emotion, yet their activation patterns

differed across instances belonging to the same category both within and between cultures (e.g., Chiao, 2015; Han & Ma, 2014). Accordingly, in all language families, emotion categories have been found to be described in terms of valence and arousal (Jackson et al., 2019). Also, categorization of affective states seems to be a consistent process across cultures, as sorting emotional instances into discrete categories is a common practice across different cultural groups (e.g., Cowen et al., 2021; Gendron et al., 2014; Jackson et al., 2016), yet the formed categories are culturally variable (e.g., Crivelli et al., 2016; Jack et al., 2012). To give an example, Jack and collaborators (2016) compared emotion perception between participants coming from the UK and participants coming from China in a forced-choice-task requiring matching dynamic facial actions with English emotion terms (i.e., "anger", "disgust", "fear", "joy", "sadness", and "surprise") and their Mandarin translations. Both groups perceived facial actions in terms of four categories that were distinguished mainly according to their valence, arousal and dominance; yet each group was found to associate specific facial actions with categories that did not have equivalent translations in the other group (e.g., "depressed" in English). In a constructionist perspective, interindividual as well as cultural differences in emotion are explained through the conceptualization of emotions as nominal kinds. As emotion categories are thought to denote heterogeneous populations of modality-specific instances, they exist because members of a culture agree that they share certain abstract features (Oosterwijk et al., 2012). Such an agreement gives emotions a social reality (cf., Barrett, 2012). As highlighted in section 1.3.2, emotion categories are not inborn but acquired socially through interactions with caregivers in which information about culturally relevant emotion categories is transmitted. Stronger evidence in favor of the cultural nature of emotion comes from adulthood, as acquiring a host culture's emotion categories is thought to be essential to acculturation to a new culture (De Leersnyder, Mesquita & Boiger, 2021).

To sum up, a constructionist approach to emotion states that emotion perception and experience is determined by people's conceptual knowledge and how they use it (see section 1.3 for a broader discussion). Therefore, differences in how people categorize affective states, as well as external sensory inputs, would lead to consequent interindividual differences in how emotions are perceived and experiences. Moreover, the conceptualization process, through both the content of emotion conceptual knowledge

and to which instances it is applied, can also determine cultural differences in emotion perception and experience.

1.4 EMOTION AND BILINGUALISM

The previous section evidenced that emotions could take on different connotations in translation between languages encoding different emotion terms. Such evidence is of considerable relevance in the modern globalized world, where bilingualism is becoming increasingly widespread (Grosjean and Li, 2013). Within this section a discussion of behavioral and neuroimaging findings on bilinguals' processing of emotionally charged stimuli will be provided. Moreover, it will be shown that the current literature is still inconclusive and possible explanations for the inconsistency between studies will be given.

Bilingualism[1] refers to the knowledge and usage of two or more languages. Yet, bilingualism cannot be reduced to knowing and using two or more languages. Indeed, a bilingual individual might acquire their languages in a different order, being it simultaneous (i.e., when languages are acquired from birth) or sequential (i.e., when a language is learnt later in life); at different ages, more (i.e., early bilinguals conventionally acquired their second language in early or middle childhood) or less (i.e., late bilinguals are thought to learn their second language after puberty) earlier in life; or in different contexts, being them naturalistic, formal or mixed. Furthermore, bilinguals can reach different levels of proficiency in their languages, being balanced (i.e., similar skills are attained in their languages across different domains) or unbalanced (i.e., one language is handled at higher levels of proficiency than the other(s)); or use their languages with a different easiness and to different degrees in their daily lives. This being the case, bilingualism goes far beyond the knowledge and use of two languages, comprising numerous dimensions that determine individual profiles of bilingual linguistic abilities throughout the lifespan. Accordingly, traditional qualitative/dichotomic approaches to bilingualism, focusing on a single specific aspect, overlooked other relevant bilingual

[1] The knowledge and usage of more than two languages is more appropriately referred to as *multilingualism*. Please, note that throughout the present dissertation I will use the term *bilingualism* to refer more broadly to knowing and using two or more languages.

dimensions that may influence bilinguals' cognitive activity and emotional life. In contrast, a quantitative/continuous approach to bilingualism is increasingly gaining ground in the cognitive neuroscience of bilingualism (e.g., De Luca et al., 2019; Sulpizio et al., 2020a). In such an approach, bilingualism is conceived as a multidimensional phenomenon, in which several static (e.g., age of acquisition) and dynamic (e.g., exposure) dimensions are interrelated. Thus, it models the full spectrum of bilinguals' abilities and experiences, allowing to draw a typification of different profiles based on the extent to which people continuously vary as bilinguals. Accordingly, a continuous approach is more ecological, as it accounts for differences in bilingual experience between and within individuals, and has the potential to provide more accurate insights into the effects of bilingualism on cognition and emotion. This approach will therefore inspire all experiments conducted on bilingual speakers discussed throughout the present dissertation.

1.4.1 Early evidence of bilinguals' different emotionality in their languages

The origin of interest in bilinguals' emotionality can be traced back to the end of the 19th century, when Freud (1893) reported cases of bi- or multilingual patients who preferred to talk about taboo and anxiogenic topics in their second language(s). Later on, post-Second World War psychoanalysts found that patients, when forced to switch to the first language, voiced repressed memories and desires (e.g., Buxbaum, 1949; Krapf, 1955). A few decades later, Marcos (1976) coined the term "emotional detachment effect" to describe sequential bilinguals' use of a second language to deal with problematic topics in therapy, suggesting that the second language, acting as a barrier, provide patients with a linguistic detachment that enable them to verbalize highly charged material. First evidence in favor of such speculations came from clinical studies showing that bilingual patients differently react to arousing stimuli (e.g., taboo words) when using different languages (e.g., Aragno & Schlachet, 1996; Movahedi, 1996), with the L1 triggering more intense reactions and higher levels of anxiety (Schwanberg, 2010). Thus, clinical studies provided researchers with insightful findings on bilinguals' differential reactivity to negative content (e.g., words, memories, topics) presented in their L1 versus second languages, suggesting that a second language would trigger a greater emotional distance. Inspired by such observations, Dewaele (see Dewaele, 2010) and Pavlenko (see Pavlenko, 2005), adopting an introspective approach, investigated bilinguals' perceived

emotionality of their languages, as well as the preferred language to express emotional contents. They observed the first language acquired was rated as more emotional than the later acquired languages, and was more likely to be used to express both positive and negative feelings. Nevertheless, the L1 was shown to be preferentially used to express affect more by L1-dominant participants than participants equally dominant in their languages or dominant in their second languages. Furthermore, a language acquired in naturalistic and mixed contexts (versus a language acquired in formal settings) was more likely to be rated as more emotional and to be preferentially selected for emotional expression. In addition, early bilinguals (versus late bilinguals) tended to rate their second language as more emotional and to frequently use it to express feelings. Such age of acquisition (AoA) effect has been later replicated by Caldwell-Harris and colleagues (2011) in a sample of Mandarin-English bilinguals, where late bilinguals judged their L1 as more emotional, whereas early bilinguals rated the two languages as equally emotions. Nevertheless, the aforementioned bilingualism-related effects on emotionality are not always so clear-cut. Indeed, a dissociation in the perceived emotionality between a language and words presented in that language emerged (Dewaele, 2010), revealing an underlying dissociation between an interpretative processing (i.e., the former) and an automatic processing (i.e., the latter) of emotionally charged stimuli (Pavlenko, 2012). Subjective measures (e.g., self-reports, questionnaires, interviews) have thus shown that bilinguals generally experience their mother tongue as more emotional than their second one(s) (Dewaele, 2008; 2010; Pavlenko, 2004, 2012). Moreover, dimensions related to bilingual experience (e.g., AoA) and to bilinguals' attitudes toward a language have been suggested to shape how bilinguals perceived their languages and affective stimuli presented in that language. Nevertheless, self-reports rely on people's interpretations and communication of their own experiences, thus being potentially subjected to confounding variables, such as motivational drives or cultural stereotypes.

1.4.2 Behavioral evidence of bilinguals' different emotionality in their languages

Contrary to introspective approaches exploring people's conscious perception of affective stimuli, cognitive approaches systematically investigate bilingual's automatic processing of emotional (versus neutral) words.

Due to their greater motivational relevance, emotionally charged stimuli have been systematically shown to display a processing advantage over neutral ones, capturing more promptly people's attention. Such processing advantage has been attested also for emotional words, irrespective of their polarity, in monolingual speakers (e.g., Citron, Weekes & Ferstl, 2013; Goh et al., 2016; Yap & Seow, 2014; for a review, see Kauschke et al., 2019). For instance, both emotion-label words (e.g., "anger") and emotion-laden words (e.g., "cancer") have been found to display greater memory effects than neutral words, being better recalled and recognized (e.g., Altarriba & Bauer, 2004; Talmi & Moscovitch, 2004). Moreover, Robinson and Altarriba (2014) found that emotion words, especially negatively-valenced ones, slow down participants' responses in a lexical decision task, a finding that they interpreted as suggestive of the interference determined by emotional words on ongoing task demands. Importantly, the authors found that emotion-laden words interfered with participants' lexical judgments to a lesser extent than emotion-label words, highlighting that they are distinct word classes in terms of both representation and processing (see also Altarriba & Bauer, 2004). In addition, greater congruency effects for both emotion-label and emotion-laden versus neutral words have emerged in affective priming paradigms (e.g., Altarriba & Basnight-Brown, 2011), again more marked for the former word class. The same processing effects (i.e., memory effects, interference effects and congruency effects) have been explored in bilingual speakers to assess the automatic processing of affective stimuli in a bilingual's two (or more) languages. For what concerns memory effects, Anooshian and Hertel (1994) administered to a sample of fluent English-Spanish and Spanish-English bilinguals a free recall task. Their findings revealed a processing advantage for emotional words presented in participants'L1 in both groups, with emotional words being recalled more frequently than neutral ones, whereas such effect failed to emerge for stimuli presented in participants' L2. The authors accounted for the lack of memory effects for L2 words suggesting that emotional words in a second language miss the emotional connotations favoring their recall. Based on this pioneering finding, Ayçiçegi & Harris (2004) presented a sample of late Turkish-English bilinguals, who were more proficient in their L2 but lived in a L2-speaking country at time of testing, with a word-rating test. Then, half participants were presented with a surprise recall task, the other half with a recognition task. Five word classes were used as experimental stimuli, that is taboo words, reprimands, positive

words, negative words, and neutral words. Their findings showed similar emotion-memory effects in the first and the second language, with stronger effects for negative words and reprimands presented in the L2. The authors interpreted the former finding as led by a deeper processing of negative stimuli in a bilingual's second language, which would be more easily tolerated due to a dampening of the associated unpleasant feelings; whereas, they attributed the latter finding to a novelty effect. According to the authors, the inconsistencies between their findings and those of Anooshian and Hertel (1994) could be determined by differences in participants' bilingual background, on the one hand, or in deepness of stimulus processing, on the other hand. Therefore, in a later study, Ayçiçegi-Dinn & Caldwell-Harris (2009) enrolled a sample of Turkish-English bilinguals, who were highly proficient in their L2 but lived in a L1-speaking country at time of testing. Participants were randomly assigned to one of four tasks differing in their depth-of-processing, three of which were deep processing tasks (i.e., a word-rating task, a translation task and a word association task) and one a shallow processing task (i.e., a letter counting task). Then, all participants were presented with a surprise recall task. Findings showed similar emotion-memory effects between the two languages, although with some slight differences between the tasks employed, leading the authors to conclude that words' emotional connotations are processed (almost) equivalently in a bilingual's two languages. Such findings thus reveal the reductiveness of the claim that the L1 is generally more emotional than a later acquired language. In addition to the experimental procedure specific to each study, already in an introspective approach, it was pointed out that some factors related to bilingual experience can shape bilinguals' perceived emotionality of a language and use of that language to express feelings (see section 1.4.1). Thus, Ferré and colleagues (2010) first tested the effect of bilingualism-related factors on bilinguals' recall of emotional words in two samples of Spanish-Catalan bilinguals. In the first experiment, participants acquired both Spanish and Catalan from early childhood, used their languages in an immersive context, and reached high levels of proficiency in both, yet they were dominant in only one of them. Findings showed equivalent emotion-memory effects in both languages, regardless the fact that participants described themselves as being more dominant in one language over the other. The second experiment was performed on Spanish-English bilinguals, who acquired their L2 later in life in instructional settings but reached a high level of proficiency in their L2. Again

emotion-memory effects were found to be of similar magnitude between the L1 and the L2, leading the authors to conclude that none of the bilingual dimensions tested (i.e., AoA, context of acquisition, language similarity) affected the automatic processing of emotional words in L2, at least in memory tasks. In a later study, Ferré, Sánchez-Casas and Fraga (2013) assessed whether similar emotionality effects between a bilingual's two languages could be replicated also in encoding tasks not focused on words' emotional content. In a first experiment, a sample of Spanish-Catalan bilinguals, who acquired both their languages in early childhood in immersive contexts, were highly proficient in both of them but dominant in one of them, were first asked to rate words with respect to their concreteness, then were administered with a free recall task. Results showed similar emotion-memory effects between the two languages. In a second experiment, a different sample of Spanish-Catalan bilinguals, with the same characteristics, was administered with a vowel counting task and then with a free recall task. Again, results showed that emotion words were recalled better than neutral ones, irrespective of language. Based on these findings, the authors concluded that at least in early, highly proficient bilinguals, who acquired both their languages in naturalistic contexts, although being more dominant in one language, emotional words are processed similarly in both their languages. El-Dakhs & Altarriba (2018) in a free recall task assessed also the effects of language exposure on emotion-memory effects in a sample of late Arabic-English bilinguals, finding a significant advantage for emotion words in both the L1 and the L2, regardless of the level of language exposure. The studies described so far thus evidence emotionality effects of similar magnitude between a bilingual's two languages, at least in the memory domain. Regarding interference and facilitation effects, bilinguals' automatic processing of emotionally charged stimuli has been mainly investigated through the Emotional Stroop task (EST), a modified version of the original Stroop task (Stroop, 1935). In the EST participants are asked to name the ink-color of printed words, while ignoring their meaning. A widely reported finding is a prolonged response time for emotion words as compared to neutral ones, as emotion words would promptly capture participants' attention interfering with color naming. This emotional Stroop effect is thought to tap onto an automatic early semantic processing (William, Mathews & McLeod, 1996), providing insights on the automatic access to emotion words in a bilingual's two languages. An inconsistent picture of bilinguals' emotionality has emerged from studies

employing the EST. On the one hand, greater interference effects of emotional words presented in the L1 (versus the L2) were found among different bilingual groups (Colbeck & Bowers, 2012; Liao & Ni, 2021; Winskel, 2013), suggesting that bilinguals do not automatically access the emotional meaning of L2 words to the same extent as in the L1. Interestingly, administering a sample of late Chinese-English bilinguals the face-word variant of the EST, Fan and collaborators (2016) found similar congruency effects between the two languages but greater interference effects in participants' L1 than L2, a result that the authors interpreted as suggestive of a more automatic access to emotional information in the L1 and of a reduced emotionality associated with L2 processing. On the other hand, other studies failed to find a difference between the two languages (e.g., Ahn & Jiang, 2023; Eilola, Havelka & Sharma, 2007; Grabovac & Pléh, 2014; Sutton et al., 2007), suggesting that emotional processing in a L2 is as automatic and efficient as that in the mother tongue. Nevertheless, it is worth mentioning the study of Eilola and Havelka (2011) on English monolinguals and proficient Greek-English bilinguals presented with an EST while monitoring their skin conductance. Behavioral results revealed similar interference effects for both negative and taboo words presented in English between the two groups, yet skin conductance indexes were significantly different, as monolinguals but not bilinguals showed more intense reactions to both negative and taboo words presented in English. Such dissociation would suggest that effects that are not detectable at the behavioral level may nonetheless exist at other processing levels, a point to which I will return when discussing the findings of Experiment 2, in which, in spite of null EST effects at the behavioral level, we observed some processing differences at the neural level. Affective priming paradigms have also been employed to investigate bilinguals' automatic emotional processing (e.g., Segalowitz et al., 2008). Crucially, Degner, Doycheva and Wentura (2012) employed both a semantic and an affective priming task: the former allowed researcher to assess the participants' level of semantic word processing in both languages, while the latter enabled them to assess automatic emotional processing in both languages. Semantic priming effects emerged in both languages, that is an automatic processing of word meaning occurred equally in the first and second language. However, whereas significant affective priming effects were found in the L1 for both French-German and German-French bilinguals, only bilinguals immersed in an L2 environment, with a high degree of L2 daily

use, showed theses effects in their L2. According to the authors, such findings were indicative of the role of language immersion and use in enhancing the affective connotations of stimuli in a second language. Indeed, many studies revealing no differences between a bilingual's two languages were carried out on bilinguals living either in a country in which both their languages were spoken (e.g., Altarriba & Basnight-Brown, 2011; Ferré et al., 2010; Sutton et al., 2007) or in a L2-speaking environment (e.g., Ayçiçegi & Harris, 2004; Conrad et al., 2011; Eilola & Havelka, 2011). On the contrary, most studies reporting differences between bilinguals' two languages were conducted in L1-speaking countries (e.g. Colbeck & Bowers, 2012; Degner et al., 2012). Moreover, similar emotionality effects between the two languages were observed for bilinguals who used either both their languages equally (Eilola & Havelka, 2011) or the L2 more frequently than the L1 (e.g., Altarriba & Basnight-Brown, 2011; Kazanas & Altarriba, 2016; Sutton et al., 2007).

To sum up, accumulating evidence from studies assessing behavioral effects draws an inconsistent picture of emotional (word) processing in bilinguals, with some attesting weaker emotional effects in a second (versus the first) language, others reporting no differences between a bilingual's two languages, and still others greater emotional effects in a second language. Accordingly, some supported, whereas others argued against, the claim of the L2 as an emotionally distant language. Different factors might have contributed to such inconsistency in findings. The first factor relates to the characteristics of the enrolled participants in terms of their bilingual experience. Indeed, participants with extremely varied language profiles (i.e., AoA, language dominance and use, proficiency, and so on) were recruited, without controlling for the potential role of these factors in shaping bilinguals' emotionality. Even when exploring whether and to what extent such factors modulated the observed effects, this was carried out mainly by considering only one bilingual aspect, thus overlooking its potential interaction with other equally important aspects in determining bilinguals' emotionality. Nevertheless, since bilingualism is not an all-of-none phenomenon but rather a continuous dimension consisting of several interrelated aspects, it is unlikely that only one factor can determine how bilinguals react to emotional stimuli. The second factor is related to the wide range of the tasks used, which might operate at different levels of processing, relying either on an automatic implicit processing (i.e., lexical decision tasks and emotional Stroop tasks)

or an explicit processing (e.g., affective judgment tasks or emotionality-rating tasks). Notably, the emotional content of words has been found to be task-relevant in explicit tasks but irrelevant in implicit ones, capturing more promptly participants' top-down attention (e.g., González-Villar et al., 2014; Liao & Ni, 2021), thus enhancing emotional processing (Hajcak & Nieuwenhuis, 2006). A third factor relies to the type of stimuli used: some recurred to emotionally positive, negative and neutral words, others included also taboo words and reprimands, still others compared emotion words with emotion-laden words. Importantly, research on bilingual's emotional processing has mainly been conducted through static stimuli, such as single words or posed facial expressions, which, although providing insightful findings, do not resemble what happens in real life when bilinguals face emotional stimuli and events. On the other hand, naturalistic stimuli, such as dynamic facial expressions or movie-clips, allow a more ecological investigation of information processing over long and complex timescales (Simony & Chang, 2020; Sonkusare, Breakspear, & Guo, 2019; Honey et al., 2012). Indeed, due to their richness in both input modality and content, they better mirror the nature of emotional experience in real life as they evoke strong emotions (Goldberg, Preminger, & Malach, 2014). Therefore, to fill this gap in bilingual literature, in Experiment 3 we explored bilinguals' emotionality through a more ecological approach, mirroring bilinguals' real-life situations with emotional experiences in a second language. This experiment was motivated by the spread of original language movies among L2 users of English thanks to the advent of online platforms for movie watching.

Moreover, behavioral effects are thought to represent an overall processing, but not to be suitable to reveal differences that might be present at intermediate stages. Indeed, there might be differences in the time course of emotional processing in a bilingual's two languages and/or processing emotional stimuli in a second language might require additional neural resources. In the next section I will describe electrophysiological and functional findings on the neural underpinnings of emotional processing in bilinguals.

1.4.3 Neuroimaging evidence of bilinguals' different emotionality in their languages

Conrad, Recio and Jacobs (2011) assessed the electrophysiological signatures of emotional word processing in late German-Spanish and Spanish-German bilinguals, presented with a visual lexical decision task in both their languages. Their findings

showed comparable early posterior negativity (EPN) and late posterior component (LPC) effects, suggestive, according to the authors, of an early sensitivity to emotional content also for emotional words in a L2. Both the EPN and LPC components have been systematically associated with emotional word processing in monolinguals: the EPN is thought to reflect an early automatic processing of emotional content driven by a prompt attentional shift toward salient stimuli, whereas the LPC has been associated with a more effortful semantic processing. Moreover, the processing of L2 words displayed a 50-100 ms delayed EPN which the authors interpreted as suggestive of a delayed visual word recognition process rather than emotional processing. Using a modified version of the lexical decision task, Opitz and Degner (2012) presented German-French and French-German bilinguals with positive, negative and neutral words, while recording their EEG signals. Their findings showed the EPN to have similar amplitudes but differences latencies between the two languages when processing emotional words, with a delay for L2 words. According to the authors, such finding might reflect a delayed lexical access to words presented in a second language, presumably due to a more demanding interference resolution in an integrated bilingual lexicon, which would in turn lead to a dampened sensitivity to emotional content presented in a L2. A lexical decision task was adopted also by Chen and collaborators (2015) with a sample of unbalanced Chinese-English bilinguals recording their ERPs. Their findings revealed an emotional effect also in the L2, yet it was delayed with respect to that observed for the L1. Crucially, the authors observed that such delayed emotional effect was different from that found in the aforementioned studies, presumably due to the different bilingual characteristics of their samples. Indeed, bilinguals in the studies by Conrad et al. (2011) and Opitz and Degner (2012) had a deeper immersive experience in the L2 that might have allowed them to more automatically respond to emotional content in a L2, whereas participants in the study of Chen et al. (2015) learnt their L2 mainly in formal settings, thus having less opportunity to engage an automatized emotional word processing in the L2. Interestingly, the authors observed emotional words to lead to an enhanced posterior negativity in the L1 emotional words but to a greater posterior positivity in the L2, thus highlighting a qualitatively (rather than quantitative) different emotional word processing in a bilingual's two languages. Consistent with the hypothesized role of language immersion and use, Vélez-Uribe and Rosselli (2021) found larger LPC amplitudes for emotional

words in participants' less proficient language, suggesting emotional processing differences between an unbalanced bilingual's two languages. Fan and colleagues (2016) administered a sample of Chinese-English bilinguals with the face-word version of the EST, in which L1 or L1 task-irrelevant emotion words were superimposed on emotional faces. Their findings showed an increased amplitude of the N250 ERP component, which has been associated with initial stages of orthographic decoding (Wong, Wu & Chen, 2014) and shown to be modulated by attention, for incongruent trials in the L1 versus the L2. The authors interpreted such evidence as suggestive of an increased attentional allocation on L1 words in incongruent conditions, which might have led participants to do more errors and to took longer to suppress the conflicting emotional meaning activated by words. According to the authors, their findings are consistent with the view that L2 triggers a less automatic activation of emotional contents.

For what concerns functional findings, Chen and colleagues (2015) explored the neural correlates of bilinguals' emotional word processing by administering an independent sample of unbalanced Chinese-English bilinguals with a lexical decision task. Positive words in the L1 were found to be associated to the weakest activation of the middle occipital gyrus (MOG), a finding that the authors interpreted in terms of a facilitated word recognition driven by the automatized access to emotional meanings in L1, especially for positive content. Moreover, in the left cerebellum, positive words were found to be less active than neutral ones in the L1, but more active than neutral ones in the L2. According to the authors, the decreased activation observed for L1 positive words suggested an easier access to L1 emotional information due to an automized recognition of those stimuli. Conversely, the enhanced activation shown for L2 positive words might stand for a greater semantic information processing compensating for a less automatized access to L2 emotional words. Thus, Chen and collaborators (2015) suggested that emotional words in one's first language, promptly capturing people's attention, would benefit from a facilitated processing, whereas emotional words in a second language would be recognized through an enhanced semantic processing. Using taboo words, Sulpizio and colleagues (2019) presented a group of highly proficient Italian-English bilinguals a lexical decision task in the MR scanner. Besides being perceived as less offensive, when presented in the L2, taboo words led to enhanced activity within the inferior occipital gyrus (IOG) bilaterally and the anterior cingulate gyrus (ACC). As in

Chen et al. (2015), the additional engagement of visual structures was interpreted by the authors as indicative of a more effortful processing of taboo words in a second language. Moreover, according to the authors, the enhanced activation of the ACC, which has been associated with social norm representation and evaluation (Zinchenko & Arsalidou, 2017), would compensate for the less automatized access to socio-pragmatic and emotional information in a L2 (Hayakawa et al., 2016). In a recent ALE meta-analysis (Dang et al., 2023) it was shown that the brain network activated for processing negative emotion words in L1 accommodates for L2 emotion processing, resulting in a slightly different L2 brain network. In particular, the two brain networks differed in the ventral pathway for emotion identification and production, with the L2 brain network showing a disconnection between the IFG and the amygdala. According to the authors, such disconnection, isolating the dorsal and ventral pathways, would account for the observed differences in emotional resonance between the L1 and L2, as the disconnection between the two pathways may lead to a weaker automaticity of emotion identification. In order to assess whether emotional language processing differs when reading in L1 or L2 at the sentence level, Citron, Michaelis and Goldberg (2020) presented German monolinguals and proficient Italian-German bilinguals with German conventional metaphors and their literal paraphrases. Metaphors have indeed been shown to trigger emotional resonance in monolinguals and to lead to consistent enhanced activity in the left amygdala (Citron & Goldberg, 2014; Mon et al., 2016). In the study of Citron and colleagues (2020), among monolinguals increased metaphoricity led to greater activity in the inferior frontal gyrus (IFG), the ACC and the left amygdala, and in the head of the right caudate nucleus in the L2. According to the authors, the former findings were suggestive of a simultaneous retrieval of lexicosemantic representations and a consequent selection of the intended meaning, which then triggered a stronger emotional engagement, whereas the latter results were indicative of a greater interference exerted by the L1 on the processing of metaphors in L2. Based on such findings, the authors hypothesized a more similar processing of literal and metaphorical meanings in a bilingual's two languages, with metaphors in a second language being not emotionally engaging as those in the mother tongue. Aiming at exploring potential emotional processing differences between L1 and L2 at the narrative level, Hsu, Jacobs & Conrad (2015) presented late, highly proficient German-English bilinguals with happy, fearful or neutral text passages from the Harry

Potter book series, in both their languages. The findings revealed different neural substrates for processing (positive) emotional text passages between the two languages. Indeed, L1 positive text passages, also rated as happier than L2 ones, triggered enhanced activity within the left precentral gyrus (PreCG), specifically in the head/face area of the somatotopic map, and the bilateral amygdala. The greater response of the amygdala to emotional stimuli in the L1 was interpreted by the authors as suggesting a dampened reaction to emotional content presented in a L2. Additionally, the enhanced activity observed in the face area for emotional texts in the L1 was associated to a less efficient embodied processing of such stimuli when presented in a L2, which would thus rely more on systematic processes than intuitive and affective ones.

From the studies described above, we can draw two main conclusions. First, in spite of inconsistent findings on bilinguals' emotional processing, neuroimaging evidence seems to suggest that some systematic differences in emotional content processing between a bilingual's two languages do exist at the neural level. Nevertheless, some studies pointed out a qualitatively different processing of emotional content in a bilingual's two languages, whereas others quantitative differences which might be further modulated by factors related to bilingual experiences, such as language immersion and use. Second, contrary to a copious behavioral evidence, neuroimaging evidence on the topic is still in its infancy, underlining the need to address more deeply the neural mechanisms underlying bilinguals' emotionality. Accordingly, Experiment 2 and Experiment 3 we intended to shed additional explanatory light on the neural underpinnings of bilinguals' resonance to emotionally charged stimuli. Determine whether bilingual speakers emotionally react to a different extent to stimuli and events might be crucial in establishing whether bilinguals will behave differently in their two languages in other cognitive domains, among which decision-making. In the next section, I will thus discuss evidence on the effect of language context on bilinguals' decisions and choices, with a special focus on morality.

1.5 MAKING DECISIONS IN A BILINGUAL'S MIND

Everyday bilinguals not only have to make not only language choices (i.e., which language to use in each communicative situation) but also political, economic, and ethical

decisions. Nevertheless, decisions are not always presented and taken in the first language, especially nowadays where bilingualism is increasingly widespread. In fact, many times we are called to decide in our L2, third or fourth (Lx) language. At the macrosocial level, for example, world security is guaranteed by deliberations agreed in the foreign languages of the various members of the United Nations. At a more practical level, we can choose to buy a direct flight, more expensive, rather than making a stopover based on the arguments presented by the customer service of a foreign airline. Therefore, it is necessary to determine whether and to what extent our judgments, choices and preferences depend on the language in use. In principle, our decisions should derive from an appraisal of the possible options and/or our preferences, and not from the language in which they are presented. Yet, research in the field of bilingualism has shown that decision-making in a second language may result in choices that are systematically different from those that would be made in the L1 (Hadjichristidis, Geipel & Keysar, 2019). People seem more analytical, and less at the mercy of their emotions, when they decide in a L2. For example, the use of a L2 reduces human aversions to loss, risk, and uncertainty, triggering more consistent and less heuristic-driven decisions (e.g., Costa et al., 2014a; Keysar et al., 2012). This phenomenon, known as the Foreign Language Effect (FLE), has been generalized to many domains of decision making and judgment, including morality.

1.5.1 The Moral Foreign Language Effect

Moral dilemmas present people with two ethically contrasting alternatives, i.e., to harm a person to save more lives (i.e., a utilitarian choice; Mill, 1998) or to spare him by letting the others die (i.e., a deontological choice; Kant, 1959). For instance, in the classic trolley problem (Foot, 1967), the decision-maker must decide whether to let a trolley kill five people or divert it to another track, killing only one. According to the dual-process theory of moral judgment, moral scenarios trigger a competition between intuition and deliberation (System 1 and System 2, respectively; Greene et al., 2001, 2008). System 1 is responsible for an automatic, swift, unintentional, emotionally driven process leading to alignment to social norms and, thus, deontological principles (e.g., “do not kill”). System 2 manages an analytical, slow, deliberate, cognitively controlled process, which is more tuned to the utilitarian morality as it carefully evaluates the cost-benefit ratio, maximizing the overall outcome (e.g., “the end justifies the means”). Thus, the automatic

emotional reaction to harm – driven by System 1 – prevent us from killing, irrespective of the benefits this crime may bring, whereas the effortful computation of potential gains – carried out by System 2 – drives us to offend, irrespective of accepted ethical standards. Hence, the FLE stands for a direct consequence, or a side-effect, of the influence that language exerts on the precarious balance between emotion and cognition (Costa, Vives & Corey, 2017). A typical finding in the FLE literature attests that, when using a L2 to make their decisions, bilinguals are less likely to choose the deontological option, being more sensitive to the outcome than to compliance with social norms (Cipolletti, McFarlane & Weissglass, 2015; Geipel et al., 2015a, b; Hayakawa et al., 2017; for meta-analyses, see, for instance, Del Maschio et al., 2022a; Stankovic, Biedermann, & Hamamura, 2022). For instance, Costa and colleagues (2014b) presented different groups of late bilinguals with the "footbridge" version of the aforementioned Trolley dilemma, in which the decision-maker can prevent the trolley from killing the five people by pushing a fat man off the footbridge, either in their first or their second language. Results showed that the rate of utilitarian choices in the L2 increased by more than half compared to the L1 condition. According to the authors, the enhanced utilitarian behavior observed for participants using the L2 was determined by a dampened emotional reaction in the second language to the act of pushing a man off the bridge. Nonetheless, other putative mechanisms responsible for the FLE have been proposed.

1.5.2 Explanatory hypotheses for the Moral Foreign Language Effect

Several explanatory hypotheses have been advanced to unravel why moral decision-making in a L2 seems to be less "moral" and/or more utilitarian in a L2 vs. a L1. The cognitive enhancement hypothesis associates the FLE with a dampened cognitive fluency that induces people to evaluate a decision-problem more conscientiously (Alter et al., 2007). Indeed, making a choice in the L2 vs. L1 is more cognitively demanding due to the higher cognitive load associated with processing a L2 (Korn, Heekeren & Oganian, 2019; Oganian, Korn & Heekeren, 2016). A less unmeditated processing might promote psychological distance, reducing emotional resonance and, consequently, weakening the influence of intuition on moral judgment (Costa et al., 2014b; Keysar et al., 2012). In turn, a feeble intuition may put on silent the default automatic emotion-driven process, turning on the rational system, which triggers a more deliberate and analytic decision making (Costa et al., 2014b). Thus, the FLE would be determined by an increased reliance

on System 2, which is more concerned with the achievement of the greater good. Conversely, according to the reduced emotionality hypothesis, the FLE would arise from "colder" emotional reactions to moral infractions elicited by decision-problems presented in a L2. Indeed, processing a L2 ends up in a weakened emotional involvement (for a review, see Pavlenko, 2017). Thus, facing a moral decision in a L2 would prevent emotions sparking gut-feeling reactions (i.e., activate System 1) that might distort judgments and choices (Greene et al., 2004), leading people to align to a lesser extent with ethical norms. Instead, the reduced access to norms hypothesis states that a dimmed morality in a L2 may result from a less fluid mental accessibility of normative knowledge (Geipel et al., 2015a, b). Moral and social rules are taught and acted upon early in life through social interactions carried out in the L1. As the language of encoding seems to be stored in episodic memories (e.g., Marian & Neisser, 2000; Schrauf & Rubin, 2000), facing a moral dilemma in the L1 vs. L2 would lead to a greater activation of the encoded ethical standards. Nevertheless, it is worth pointing out that cognitive control, emotionality, and normative knowledge might act synergically in the emergence of the FLE, letting intuitive System 1 or deliberative System 2 guide the actual decision or judgment (Costa et al., 2017).

1.5.3 Bilingualism-related determinants of the Moral Foreign Language Effect

The relative contribution of intuition and deliberation to decision-making in a L2 may be modulated by individual variability in bilingual experience (Del Maschio et al., 2022a; Stankovic et al., 2022). Indeed, there is growing evidence in current literature that the FLE does not affect all bilinguals to the same extent (e.g., Wong & Ng, 2018; Winskel & Bhatt, 2019; Del Maschio et al., 2022b). Operationalizing bilingualism quantitatively, i.e., as a gradient measure, rather than qualitatively, i.e., an all-or-none phenomenon, allows researchers to draw a typification of different bilingual language profiles based on the extent to which people continuously vary as bilinguals. Consequently, besides being more ecological, adopting a continuous approach to investigating the FLE has the potential to shed light on the bilingual dimensions affecting decisions and judgments (Del Maschio et al., 2022b). Indeed, acquiring and managing multiple languages in daily communication have been shown to inflect neuroplasticity, leading to several structural and functional modifications in the bilingual brain (e.g., Berken et al., 2016; Singh et al., 2018; Del Maschio et al., 2019). For instance, Sulpizio et al. (2020a) found that L2 age

of acquisition (AoA), L2 proficiency and L2 daily exposure interactively reorganize bilinguals' functional connectivity of both the language and control networks. Moreover, it has been shown that dynamic bilingual dimensions such as L2 proficiency and L2 dominance might alter bilinguals' emotional processing (e.g., Degner et al., 2012; Simcox et al., 2012; Costa et al., 2014b; Pavlenko, 2017). Therefore, these bilingual background-related differences in language processing, cognitive control and emotional involvement might significantly reverberate on decision-making processes, with inevitable effects on the FLE (Del Maschio et al., 2022b). Indeed, the potential role of several bilingual dimensions – L2 AoA, L2 proficiency and L2 exposure, has been contextualized within each explanatory hypothesis. L2 AoA is considered a static bilingual measure as it refers to the age of first oral or written exposure to the L2, i.e., when the L2 began to be spoken, listened, written, or read. L2 proficiency stands for the competence achieved in speaking and understanding a second language. L2 exposure refers to bilinguals' degree of daily immersion in L2, i.e., how many hours per day they spent speaking, listening, reading, and writing in a L2. In all explanatory hypotheses, an enhanced utilitarian vs. deontological decision-making would be observed for a late vs. an early L2 AoA, a lower vs. a higher L2 proficiency, and a minor vs. a major L2 daily exposure. In consonance with the cognitive enhancement hypothesis, heightened cognitive resources are requested to process a language acquired beyond critical periods in development, less consolidated with respect to the acquired skills in production and comprehension, or less "dominant" in daily life. According to the reduced emotionality hypothesis, a shrunk emotional resonance is associated with a language which has been acquired later in life, is mastered to a less extent, or is less used in daily conversations. Following the reduced access to norms hypothesis, language-dependent access to normative knowledge is triggered to a lesser degree by a language which a bilingual has not acquired and experienced in childhood, in which they are less confident, or to which they are less exposed in activities of daily living. However, the effect of bilingual dimensions has not been consistently reported in literature. In their meta-analysis, Circi and colleagues (2021) found a robust, yet heterogeneous, effect of language context on participants' decisions in moral dilemmas, with increased utilitarian tendencies in a L2 versus L1. Crucially, L1-L2 similarity was observed to significantly moderate the FLE, with effect sizes significantly different from zero for languages belonging to different linguistic branches (e.g., Spanish

and English), but null effects for languages within the same linguistic branch (e.g., German and English). The meta-analysis of Stankovic, Biedermann and Hamamura (2022) evidenced a robust foreign language effect in personal moral dilemmas, that was modulated by participants' self-reported proficiency, with lower proficiency levels associated with an increased willingness to endorse the utilitarian option. Yet in their meta-analysis, Del Maschio et al. (2022a) highlighted a reliable effect of language context on participants' moral choices that was not modulated by bilingual language experience or methodological issues. Such inconsistencies between meta-analytic evidence might be partly due to differences in the way bilingual measures have been collected throughout different studies. For instance, regarding proficiency, in most of the studies proficiency was assessed subjectively, while in a few others through objective measures, thus making any comparison of results problematic. Moreover, contradictory findings could be traced back to the conceptualization of bilingualism adopted. Indeed, as we highlighted at the beginning of chapter 1.4, as bilingualism intrinsically comprises several interrelated dimensions, it is hardly likely that a single bilingual dimension may lead to the observed FLE. Thus, a continuous and multidimensional approach to bilingualism has the potential to bring to light subtler interactive effects of bilingual experience on decision-making. Indeed, Experiment 4 and Experiment 5 were motivated by the intention to discover which bilingual dimensions are actually responsible, on their own or in interaction with one another, of the observed effect of language context on bilinguals' decisions and judgments.

1.5.4 Neuroimaging evidence for the Foreign Language Effect

Although the FLE has been extensively investigated, the majority of FLE literature has been built upon behavioral studies, thus largely overlooking the neural underpinnings of decision-making in a L2. To date, only few recent studies explored the neural underpinnings of the FLE, trying to determine whether the effect was attributable to an increased deliberation, a reduced emotionality or both (e.g., He et al., 2021; Liu et al., 2021, 2022). For instance, in a functional magnetic resonance imaging (fMRI) study He et al. (2021) examined the interplay between language and emotion in decision-making. They presented Chinese-English bilinguals with a gambling task, in which feedback were given either in L1 or in L2. A different processing of valenced words in L1 and L2, which was crucial for the subsequent decision behavior, was observed. Indeed,

negative feedback in L2 determined enhanced activation of the right dorsolateral prefrontal cortex (dlPFC), a brain region associated with regulation of risk-taking behavior (Christopoulos et al., 2009). Furthermore, participants were more willingness to gamble after positive feedback presented in the L2 vs. L1. This positivity bias in the L2 was associated with an increased hippocampal activity for decisions made after positive feedback, indicating that positive information prompted a greater declarative memory formation in a L2. Accordingly, the authors suggested that bilinguals were more focused on positive stimuli when deciding in a second language. The interaction between cognitive load (high vs. load), emotional involvement (negative vs. neutral) and language context (L1 vs. L2) was further explored by Liu and colleagues (2021) through a lexicosemantic task, followed by an even-probability gambling task. Only in L1 cognitive load was found to promote emotional processing, as evidenced by increased activity in left amygdala and right insula and an enhanced connectivity with the reward-related striatum. This enhanced emotional reactivity, in turns, might lead to impulsive decision making, as suggested by positive correlations between gambling ratio and left amygdala activation for negative words in high loaded contexts. On the contrary, in L2 cognitive load led to a significant connectivity between the insula and the parahippocampal gyrus, a region associated with declarative memory, evidencing a prevalent semantic processing which, in turn, may trigger a more rational decision-making. The complex interaction between cognitive load, emotionality, and language on decision-making was further inspected in an ERP study (Liu et al., 2022). A significant three-way interaction between language, cognitive load, and emotion on P3 amplitude was found in gambling trials. In high loaded (HL) contexts, the P3 was more positive after judging L1 negative words, whereas the P3 was more positive for L2 neutral words. Furthermore, the correlation between P3 amplitude and participants' tendency to bet rationally was negative in L1 contexts but positive in L2 contexts. As the P3 component is thought to be involved in allocating cognitive resources (Polich, 2007), its greater amplitude in L1 might suggest that cognitive load enhanced participants' emotional reactivity, leading them to bet irrationally. On the other hand, in the L2 the increased allocation of cognitive resources may have hampered emotional processing, triggering more rational bets. It is worth noting, however, that these results reflect more experimentally suited decision-making, as they were obtained in gambling studies. Thus, future research should extend the

examination of the neural underpinnings of bilinguals' decision-making to other domains, possibly in the context of real-life choices to resemble what really happens when we decide in a L2. Moreover, even when investigating the neural dynamics of the FLE, a continuous approach to bilingualism should be implemented to unravel whether the different bilingual dimensions may be individually or synergically effective in driven bilinguals' decisions and judgments. Thus, assessing whom, when, and to what extent the FLE emerges may help promoting better, i.e., less distorted, and wiser choices.

1.6 EXPERIMENT 1 (INTRODUCTION): "LANGUAGE SHAPES EMOTION: EXPLORING THE RELATIONSHIP BETWEEN VOCABULARY SIZE AND CATEGORICAL PERCEPTION OF EMOTION"

This section refers to the study "*Language shapes emotion: Exploring the relationship between vocabulary size and categorical perception of emotion*" in preparation to be submitted in a peer-reviewed journal.

As highlighted in section 1.3, psychological constructionist approaches assign language a constitutive role in emotions (e.g., Barrett, 2011; Lindquist, 2013). Language is thought to fund the development and organization of emotion conceptual knowledge, which is used to categorize internal and external feelings into discrete emotion categories in a given situation. Indeed, words support the acquisition of conceptual knowledge across development, allowing children to cluster different instances of the same kind into a single category based on their commonalities (Hoemann, Xu & Barrett, 2019). Similarly, words as "joy" make children acquire the emotional categories relevant to their cultures (Nook et al., 2017). In fact, children acquire emotion concepts gradually, as language development unfolds (Widen, 2013). Once acquired, emotion conceptual knowledge keeps growing and re-organizing throughout adolescence (Nook et al., 2017, 2020; O' Kearney & Dadds, 2004) and even in adulthood (Doyle & Lindquist, 2018; Fugate et al., 2010).

Through emotion words, people would thus categorically perceive different emotional instances. Categorical perception (CP) refers to our tendency to perceive the world through previously formed categories, by which we maximize inter-category differences and minimize intra-category differences (Goldstone & Hendrickson, 2010). Specifically, CP occurs when stimuli varying along a continuum are perceived in terms of discrete categories divided by a sharp boundary. Accordingly, stimuli across the category boundary would be distinguished more accurately than stimuli within the same category (Harnad, 1987). CP has conventionally been tested by means of an identification task and a discrimination task. The identification task presents participants with stimuli varying along a linear continuum, each of which should be identified as belonging to one or the other category. If participants show CP, they should group stimuli into one category

up to a certain point along the continuum and then into the other category. However, a sharp boundary between the two categories is not sufficient to determine CP (Goldstone, 1994; Goldstone & Hendrickson, 2010). CP is indeed defined by an improved performance for between-category than within-category stimuli, the between-category advantage, which is evaluated in the discrimination task (Harnad, 1987). In the AB-X discrimination task, participants are presented with two subsequent stimuli (A and B) followed by the target stimulus X and are instructed to discriminate whether X is identical to A or B, being the difference between A and B equal in all trials.

Morphed emotional faces have been reported to show CP (e.g., Calder et al., 1996; Campanella et al., 2002; Jacques & Caharel, 2022; McCullough & Emmorey, 2009). According to a conceptual account of emotion CP (e.g., Barrett, Lindquist & Gendron, 2007; Fugate, Gouzoules & Barrett, 2010; for a review, see Fugate, 2013), emotion conceptual knowledge would be used to make meaning of the perceived facial expressions in terms of discrete emotion categories (but see, e.g., Ekman, 1992, for a perceptual account of CP).

The emotion concepts prompted in a given situation would thus join the perceptual processing itself to generate an emotional instance (Barrett, 2017). Accordingly, emotion conceptual knowledge has the potential to shape the emotion being constructed (Barrett, 2011). Any interindividual difference in emotion conceptual knowledge would thus lead people to differently cluster emotions into categories (Brooks & Freeman, 2018). As reported in section 1.3.2, parents' use of emotion words in interactions drive children's acquisition of emotion concepts, ultimately influencing their emotion perception and understanding (Shablack, Becker & Lindquist, 2020). Therefore, children with greater opportunities to learn emotion words in interactions with caregivers would be more likely to develop structured emotion concepts and hence superior socio-emotional abilities (for a review, see Shablack & Lindquist, 2019). Crucially, a growing body of evidence reported a consistent association between language development and emotional competence in children (Bosacki & Moore, 2004; Bruce, Ermanni & Bell, 2024; Grosse & Streubel, 2024; Ornaghi & Grazzani, 2013). Nevertheless, the nature of such relationship in adulthood is largely overlooked. Yet the organization of emotion conceptual knowledge may be further modelled later in life through new learning and experiential opportunities.

Experiment 1 thus tested the relationship between vocabulary knowledge and categorical perception of emotional faces morphed along a fear-to-happiness continuum, assuming the hypothesis that language shapes emotions. First, CP for morphed faces was evaluated by means of an identification task and an AB-X discrimination task. If morphed faces are categorically perceived, (a) in the identification task the categorization of faces as happy along the continuum should shift sharply, establishing a categorical boundary; (b) in the discrimination task, participants should be more accurate when face A and face B cross the categorical boundary than they belong the same category. Then, assessing whether a tight relationship between conceptual knowledge and emotions exists, correlations between participants' vocabulary size and the degree in which they categorically perceived emotional morphed faces were computed. As conceptual knowledge is used to categorize the incoming perceptual information into a given emotion (Barrett, 2017), and interindividual variability in conceptual knowledge may result in slight differences in the categorization of emotions (Brooks & Freeman, 2018), we hypothesized that a broader vocabulary knowledge will be associated to a stronger categorical perception of morphed faces. We further tested whether emotion categorical perception was related to participants' trait emotional intelligence, conceived as a set of self-perceptions and beliefs about their own emotional abilities (Petrides & Furnham, 2000).

1.7 EXPERIMENT 2 (INTRODUCTION): "NEUROCOGNITIVE MECHANISMS OF EMOTIONAL INTERFERENCE IN NATIVE AND FOREIGN LANGUAGES: EVIDENCE FROM PROFICIENT BILINGUALS"

This section refers to the study "*Neurocognitive mechanisms of emotional interference in native and foreign languages: Evidence from proficient bilinguals*"[2] by Del Maschio et al. 2024.

As mentioned in section 1.3.6, constructionist accounts of emotion assume that language provides a context for the construction of emotions. Accordingly, emotion perception and experience would differ across languages encoding different emotion terms (Lindquist, 2017). This question is of concern in an increasingly global world, where the majority of people are bi- or multilingual.

Consequently, many researchers are focusing on the relationship between emotion and bilingualism, aiming at discovering whether bilinguals' L1 and L2 differ in their emotional resonance. Self-report measures revealed that generally bilinguals feel more spontaneous and emotional in their L1 vs. L2. Nevertheless, an inconsistent picture of bilinguals' emotional processing emerged from behavioral studies using objective measures, finding either a reduced emotionality in the L2 vs. L1 (e.g., Anooshian & Hertel, 1994; Colbeck & Bowers, 2012; Degner, Doycheva & Wentura, 2012; but see, for instance, Caldwell-Harris et al., 2011, for greater emotional effects in the L2 vs. L1), or similar emotional processing mechanisms in both languages (e.g., Ayçiçegi-Dinn & Caldwell-Harris, 2009; Ferré et al., 2013).

These inconsistences may be ascribed, at least in part, to the diversity of methods and tasks employed in previous studies (see, Kazanas, McLean & Altarriba, 2019). Indeed, many different experimental paradigms have been used in behavioral studies, e.g., lexical decision (e.g., Ponari et al., 2015), word recall (e.g., Ferré et al., 2010) and affective priming (e.g., Degner et al., 2012). As highlighted in section 1.4.2, such tasks tap onto

[2] Del Maschio N, Sulpizio S, Bellini C, Del Mauro G, Giannachi M, Buga D, Fedeli D, Perani D, Abutalebi J (2024) Neurocognitive mechanisms of emotional interference in native and foreign languages: Evidence from proficient bilinguals. *Front Behav Neurosci 18*: 1392005. https://doi.org/10.3389/fnbeh.2024.1392005

different levels of processing, either automatic or explicit, thus being influenced by the emotional content of stimuli to a different extent.

Remarkably, bilinguals' emotional processing has so far been little investigated at the neural level (e.g., Chen et al., 2015; Hsu, Jacobs, & Conrad, 2015; Sulpizio et al., 2019). To fill this gap, in Experiment 2 we aimed at shedding additional explanatory light on the neural underpinnings of emotional processing in a bilingual's two languages by pairing an emotional interference paradigm (the Emotional Stroop Task – EST) and fMRI.

In the common emotion-word version of the EST (Gotlib & McCann, 1984; Williams, Mathews & MacLeod, 1996), participants are required to override interference from distracting emotional information (i.e., the emotional content of a word) to perform the task (i.e., naming the ink color in which the word is presented). The hallmark of the EST is an interference effect – termed the 'Emotional Stroop effect' – evidenced by longer response times (RTs) and/or reduced accuracy rates for emotionally negative words (e.g., 'death') than neutral words (e.g., 'closet'). Though the specific mechanisms responsible for this effect are still debated (see, Algom, Chajut & Lev, 2004), emotional vs. neutral words would be processed more efficiently as they tend to automatically capture implicit attention (e.g., Williams, Mathews & MacLeod, 1996), presumably due to their motivational and adaptive relevance (Lang, Bradley & Cuthbert, 1990).

At the neural level, interference tasks in emotionally charged contexts have been associated with enhanced activations in regions involved in cognitively controlled processes, such as the dlPFC and the ACC, but also in fronto-limbic and fronto-insular areas underlying the processing and regulation of emotional stimuli (e.g., Cromheeke & Mueller, 2014; Hung et al., 2018). Notably, performing the EST has been observed to recruit fronto-limbic regions in monolinguals, although stimulus features (e.g., positive vs. negative valence), task variants (e.g., the classic 'Color-Word' version vs. the 'Word-Face'), and task demands (e.g., high vs. low emotional conflict) may lead to specific patterns of brain activity (Song et al., 2017).

Previous behavioral studies using the EST led to inconsistent findings, discovering either a greater sensitivity to emotional contents presented in L1 vs. L2 (e.g., Eilola & Havelka, 2011; Winskel, 2013), or no differences between a bilingual's two languages (e.g., Eilola, Havelka & Sharma, 2007; Grabovac & Pléh, 2014). As we previously

highlighted, dimensions of L2 background have been found to significantly contribute to these inconsistencies. Indeed, processing of emotional information does not seem to differ significantly between two languages in bilinguals who are highly proficient in both their languages and/or immersed in bilingual environments (e.g., Eilola, Havelka & Sharma, 2007; Grabovac & Pléh, 2014; Sutton et al., 2007). On the contrary, late unbalanced bilinguals with a lower proficiency in their L2 have been found to activate emotion words less automatically in their L2 (Winskel, 2013)

In Experiment 2 we examined, with behavioral and fMRI data, emotionality effects on bilinguals' word processing during EST execution, in a sample of 36 first-language speakers of Italian who were first exposed to English during childhood, mainly in instructional settings rather than immersion, and who were proficient in their L2 at time of testing. Accordingly, we expected to observe similar emotional interferences across the two languages, mainly as a function of proficiency attained in their L2. Specifically, at the behavioral level, we hypothesized a similar pattern of word processing in both languages, with longer RTs and/or lower accuracies for emotional versus neutral words (i.e., an Emotional Stroop effect), but no significant interaction between word type and language. Moreover, at the neural level, we predicted brain activity to differ for emotional versus neutral words in frontal-subcortical networks involved in emotional processing and control, but again no significant interactions between word type and language.

1.8 EXPERIMENT 3 (INTRODUCTION): "ORIGINAL LANGUAGE VERSUS DUBBED MOVIES: EFFECTS ON OUR BRAIN AND EMOTIONS"

This section refers to the study "*Original language versus dubbed movies: Effects on our brain and emotions*"[3] by Bellini et al. 2024. With Experiment 2 we explored the neural correlates of emotional processing in a bilingual's two languages by means of the color-word version of the EST. In spite of any behavioral effect, we found that emotional words in L1 versus L2 led to a more intense response in posteromedial brain regions involved in socioemotional processing, supporting the hypothesis of an increased sensitivity to emotional information presented in a bilingual's first language. Here we adopted a more ecological approach to investigate the neural underpinnings of bilinguals' emotional processing, coupling fMRI with a naturalistic viewing paradigm (i.e., original vs. dubbed versions of emotionally valenced movie clips).

As stated in the previous section, despite copious research on the topic, bilinguals' emotional processing is still far from being clearly determined, especially at the neural level. Different individual (e.g., bilingual experience) and methodological (e.g., tasks used) factors may have led to the depicted inconsistencies (Liao and Ni, 2021). Notably, interindividual variability in bilingual language experience (i.e., L2 AoA, proficiency, immersion, exposure) has been overlooked in many studies, although it has been shown to shape bilinguals' reaction to emotional stimuli (e.g., Colbeck & Bowers, 2012; Degner et al., 2012; Ferré et al., 2018). Furthermore, research on bilingual emotional processing has been conducted mainly through isolated, static affective stimuli, such as single words or posed facial expressions. Such an approach does not closely resemble what happens when bilinguals face real-life emotional stimuli, which are intrinsically dynamic and multidimensional. On the contrary, naturalistic viewing paradigms (e.g., movie clips) allow a more ecological investigation of information processing over long and complex timescales (Honey et al., 2012; Simony & Chang, 2020; Sonkusare, Breakspear & Guo, 2019). Recently, the neural correlates of emotional processing have been explored through naturalistic emotional stimuli in healthy subjects (e.g., Goldberg, Preminger &

[3] Bellini C, Del Maschio N, Gentile M, Del Mauro G, Franceschini R, Abutalebi J (2024) Original language versus dubbed movies: Effects on our brain and emotions. *Brain Lang 253*: 105424. https://doi.org/10.1016/j.bandl.2024.105424

Malach, 2014; Koide-Majima, Nakai & Nishimoto, 2020; Mackes et al., 2018), typical development (e.g., Camacho, Karim & Perlman, 2019; Karim & Perlman, 2017) and psychiatric patients (e.g., Gruskin, Rosenberg & Holmes, 2020). However, to the best of our knowledge, no such approach has been adopted with bilinguals.

Yet, watching English-speaking movies is increasingly common among second-language speakers of English due to the spread of streaming media services and platforms. Television is proving to be a powerful medium for audiences to absorb emotional input from a variety of shows presented by a variety of people (Dewaele et al., 2021). Indeed, the combination of verbal, vocal, and visual input it provides allows L2 users to develop the ability to weigh emotionality, ultimately improving socio-pragmatic knowledge about the communication and perception of emotion (Brown, Iwasaki & Lee, 2016). Thus, in the present study we investigated emotional processing in a bilingual's two languages by testing the effects of emotionally charged movie clips in L1 vs. L2 on brain activity. To this aim, in the MR scanner, 52 Italian-English bilinguals were presented with positively (i.e., fun), negatively (i.e., sadness), or neutrally valenced movie clips, either in their dubbed Italian version (i.e., L1) or in their original English version (i.e., L2).

In a constructionist perspective, a reduced emotional resonance of the L2 (vs. L1) may be attributable to a difference in how closely emotion concepts are associated with L2 (vs. L1) emotion words. Accordingly, we hypothesized that emotional movie clips presented in L1 vs. L2 would lead to enhanced activity in brain regions involved in semantic processing such as temporal lobe structures (Binder, 2009; Satpute & Lindquist, 2019, 2021). Likewise, we expected a specific effect on the amygdala with functional responses being more pronounced in L1, since the amygdala has been consistently associated with emotional processing (Phelps & LeDoux, 2005; Zald, 2003). Moreover, adopting a continuous approach to bilingualism (see section 1.4 for a broader discussion), we hypothesized amygdala responses to stimuli in L2 to be modulated by participants' bilingual profile (i.e., L2 proficiency, L2 immersion, and L2 exposure), as it has been shown that such dimensions may influence bilinguals' emotional processing, with higher levels of proficiency and daily exposure leading to a more native-like emotional response (e.g., Degner et al., 2012; Costa et al., 2014b; Pavlenko, 2012, 2017).

1.9 EXPERIMENT 4 (INTRODUCTION): "FOREIGN TO WHOM? CONSTRAINING THE MORAL FOREIGN LANGUAGE EFFECT ON BILINGUALS' LANGUAGE EXPERIENCE"

This section refers to the study "*Foreign to whom? Constraining the moral foreign language effect on bilinguals' language experience*"[4] by Del Maschio et al. 2022b. This experiment was conducted to test whether (and to what extent) the use of a second language influence bilinguals' moral decision-making, by further exploring the potential modulatory effects of individual differences in bilingual experience on the foreign language effect.

As highlighted in section 1.5, the FLE describes the phenomenon whereby making decisions in an L2 can lead to choices that are systematically different from those that would be made in the L1. Within the domain of moral decision-making, when people make decisions in an L2, they are less likely to act deontologically being more concerned with the outcome than with conforming to social norms (Cipolletti et al., 2015; Geipel et al., 2015a, b; Hayakawa et al., 2017).

As detailed in section 1.5.1, dual-process theories of moral judgment state that moral scenarios trigger a competition between intuition and deliberation (System 1 and System 2, respectively; Greene et al., 2001, 2008). Thus, the FLE stands for a direct consequence, or a side-effect, of the effect of language on the unstable balance between emotion and cognition (Costa et al., 2017). I invite the readers to refer to section 1.5.2 for a broader description of the explanatory hypotheses proposed for the FLE. Briefly, according to the *cognitive enhancement* hypothesis, the FLE would be driven by a dampened cognitive fluency that induces people to evaluate a decision-problem more conscientiously (Alter et al., 2007). Conversely, the *reduced emotionality* hypothesis associated the FLE with "colder" emotional reactions to moral infractions triggered by decision-problems presented in a L2. Finally, in the *reduced access to norms* hypothesis, a dimmed morality in a L2 would stem from a less fluid mental accessibility of normative knowledge (Geipel et al., 2015a, b).

[4] Del Maschio N, Del Mauro G, Bellini C, Abutalebi J, Sulpizio S (2022) Foreign to whom? Constraining the moral foreign language effect on bilinguals' language experience. *Lang Cogn 14*(4): 511-533. https://doi.org/10.1017/langcog.2022.14

Moreover, the relative contribution of intuition and deliberation to decision-making in a L2 may be further modulated by individual differences in bilingual experience. Indeed, the FLE seems not to affect all bilinguals to the same extent (e.g., Wong & Ng, 2018; Winskel & Bhatt, 2019; Del Maschio et al., 2022b). Research is thus increasingly investigating the putative influence of such variables on bilinguals' patterns of moral responding. Additionally, the potential role of these bilingual dimensions has been contextualized within each explanatory hypothesis, as stated in section 1.5.3. In summary, all explanatory hypotheses predict an enhanced utilitarian vs. deontological decision-making for a late vs. an early L2 AoA, a lower vs. a higher L2 proficiency, and a minor vs. a major L2 daily exposure. However, inconsistent findings on the effect of such bilingual measures emerged (for reviews, see Del Maschio et al., 2022a; Stankovic et al., 2022). This might be due to not only differences in the way bilingual measures have been collected throughout different studies, but also the conceptualization of bilingualism adopted.

Previous studies on the FLE mainly characterized bilingualism as a qualitative experience or narrowed their interest on individual bilingual dimensions. Yet, as bilingualism intrinsically comprises several interrelated dimensions, it is hardly likely that a single bilingual dimension may lead to the observed FLE. On the contrary, a continuous approach to bilingualism has the potential to bring to light subtler interactive effects of bilingual experience on decision-making. Therefore, in the present study we explored the FLE by means of two complementary analytic approaches. To this aim, a sample of 198 Italian-English bilinguals was presented with moral dilemmas either in their L1 (N= 96) or in L2 (N= 102). First, in a between-group analysis, we assessed the effect of language on participants' moral decisions, norm judgments, and emotional distress. Then, adopting a continuous approach to bilingualism, we focused on participants assigned to the L2 condition assessing whether bilingual dimensions (i.e., L2 AoA, L2 proficiency, and language dominance) further modulated their moral decisions and judgments, as well as their emotional reactions.

1.10 EXPERIMENT 5 (INTRODUCTION): "BOUNDARIES OF THE FOREIGN LANGUAGE EFFECT UNDER CONDITIONS OF UNCERTAINTY"

This section refers to the study "*Boundaries of the foreign language effect under conditions of uncertainty*", which is currently under review in a peer-review journal. This experiment was intended to extend the results obtained in Experiment 4 to uncertain conditions, by further exploring whether potential effects of interindividual variability in bilingual experience on the FLE are influenced by individual dispositions toward risk and reflectiveness. Indeed, in Experiment 4, we observed a dilemma-specific effect of language on moral decision-making, suggesting that the framing of moral questions might be crucial to trigger or not the FLE. Moreover, we found that dimensions of bilingual language experience influenced to some extent participants' moral decision-making. Thus, many different factors, other than bilinguals' characteristics and emotional reactions, may contribute to the classic FLE. Thus, in Experiment 5, we tested the effects of both language context and problem condition (certain vs. uncertain) on participants' moral choices, norm judgments and emotional distress. Then, individual and interactive effects of L2 background on the aforementioned variables were assessed. Finally, we inspected whether significant effects of L2 background on participants' moral decision-making and emotional reactions were further modulated by traits such as risk-taking attitude and cognitive style.

Although reported in several domains of decision-making and judgments (Hadjichristidis et al., 2019), the FLE has mostly been investigated through decision-making contexts characterized by certainty and known risk. In certain contexts, all relevant alternatives are known, each leading to a specific outcome. The typical structure of moral dilemmas reflects certainty, as the outcomes of the proposed alternatives are deterministic (e.g., "If you push the man on the footbridge, five people will be saved; if you don't, five people will be killed"). In contexts of known risk, all relevant alternatives are known, and for each alternative the probabilities of all outcomes can be calculated. The architecture of certain types of gambling (e.g., lotteries) reflect known risk, as, for instance, participants are asked to choose between the sure option of receiving € 0.50 or gamble to get nothing or €1 at chance levels.

In such contexts there is no space for uncertainty, as outcomes and probabilities of their occurrence are given for sure, thus allowing people to implement optimal strategies. Nevertheless, in the majority of daily decision-making situations the probability of future events and their possible outcomes cannot be precisely anticipated (Mousavi & Gigerenzer, 2014): some of the alternatives and outcomes, in addition to their probabilities, are not known for certain.

The current work thus aimed at filling this gap in current literature by inspecting the FLE in decision-making contexts characterized by uncertainty, which are the rule rather than the exception in real-life. To this end, we administered to a sample of 339 Italian-English bilinguals, in either the L1 (N= 168) or the L2 (N= 171) context, two kinds of problems endowed with outcome uncertainty: 1) uncertain moral dilemmas, requiring to choose between a utilitarian or a deontological option; 2) exploration-exploitation problems, demanding a decision between exploiting an already known source of reward, or exploring the environment to find new sources of reward.

First, in a between-group analysis, we investigated the effects of language context (L1 vs. L2) and problem condition (certain vs. uncertain) on participants' moral decisions and judgments. As in Experiment 4, the perceived emotional distress triggered by each scenario was also evaluated to test the hypothesis of a shallower emotionality in a second language (e.g., Caldwell-Harris, 2015; Costa et al., 2014b).

Then, adopting the analytic approach of Experiment 4, we investigated the effects of participants' L2 background, cognitive style, and risk-taking attitude on bilinguals' decision-making. Thus, we run a within-group analysis on participants assigned to the L2 context, assessing the effects of individual differences in L2 background (i.e., FL proficiency, FL exposure, and FL immersion) on their choices and perceived emotional distress were modulated by individual differences in FL background. We further tested for potential interactions between significant effects of L2 background and decision-makers' traits on the aforementioned variables, inspecting whether effects of bilingual dimensions were influenced by individual dispositions toward risk and reflective thinking. Such measures were analyzed to address a limitation of Experiment 4, in order to inspect whether they might be responsible (at least in part) for the observed bilingual effects or the null effects. Indeed, increased reflective thinking, as measured by the CRT,

has been shown to be associated with enhanced utilitarian tendencies (e.g., Paxton, Unger, & Greene, 2012; Pennycook et al., 2014). Moreover, it has been suggested that people with greater risk-taking propensity likely underestimated the probability of occurrence and the magnitude of the effects when making ethically challenging decisions (Vinson et al., 2020).

Based on previous evidence on monolingual (e.g., Kortenkamp & Moore, 2014) and bilingual individuals (e.g., Hadjichristidis, Geipel & Savadori, 2015), we expected to observe the FLE also in uncertain scenarios. Consistent with Experiment 4, we also assumed that the dimensions of L2 background would interactively modulate both decisions and emotional reactions in L2 contexts. Specifically, we hypothesized both utilitarian (i.e., moral dilemmas) and exploratory tendencies (i.e., exploration-exploitation problems) to decrease with higher levels of proficiency and exposure to the L2, as well as continuous L2 usage in immersive contexts. Conversely, we predicted enhanced emotional distress for participants with higher levels of L2 proficiency, exposure and immersion. Furthermore, as the propensity toward reflective (vs. intuitive) thinking has been shown to predict utilitarian (vs. deontological) moral judgements (e.g., Paxton, Ungar & Greene, 2012), and risk and novelty seeking to favor exploration (e.g., Wittmann et al, 2008), we anticipated that measures of cognitive style and risk attitude would modulate significant effects of L2 background.

Through Experiment 5, we thus aimed at gaining a more ecological understanding of the FLE, through a more comprehensive picture of its psychological underpinnings, the etiology and characteristics of which remain poorly understood.

2 AIM OF THE WORK

Growing evidence shows that language aids the construction of emotions, supporting the development of priors that shape the organization of conceptual knowledge and its use to interpret incoming sensations in terms of emotions. Conceptual knowledge of emotions consists of culturally endorsed concepts referring to the defining features of each emotion, constituting what people know about emotions. Crucially, emotion words are thought to help the acquisition and organization of such concepts, grouping together heterogeneous instances sharing some distinctive features. Accordingly, languages that use a different emotion word to label an emotion concept would also differ in how that emotion is perceived and experienced. An increasing body of findings indeed shows that emotions vary with respect to their meaning and experiential connotation across languages. Nowadays, with more people speaking more than one language, it becomes critical to determine whether emotional resonance differs based on the language in which stimuli are processed. The present dissertation aims at shedding additional explanatory light on the nature of the relationship between language and emotion, providing evidence on both monolingual and bilingual speakers. Additionally, as emotions guide our behavior, potentially shaping our choices, this study also explores whether bilinguals make different decisions in their languages. A combination of bilingual assessments, behavioral measures and neuroimaging techniques are employed to investigate such complex relationship. In particular, Experiment 1 (Bellini et al., in preparation) inspects the association between breadth of conceptual knowledge and categorical perception of emotion from morphed faces in a sample of monolinguals. Experiment 2 (Del Maschio et al., 2024) investigates, both at the behavioral and neural level, the effects of language context on emotional interference control in a sample of Italian-English bilinguals. Experiment 3 (Bellini et al., 2024) goes further by exploring the neural correlates of processing emotional naturalistic stimuli, such as movie clips, in a first vs. second language. Experiments 4 (Del Maschio et al., 2022b) and 5 (Del Maschio et al., submitted) examine the effect of language context on moral decisions and judgments when using a second versus a first language. These experiments proceed linearly in investigating the relationship between language and emotion, starting with monolinguals and moving to bilinguals, ending up in a related research area, decision-making. The conclusions drawn from our results are far-reaching and provide new insights on the language-emotion link.

3 RESULTS

3.1 EXPERIMENT 1 (RESULTS)

One participant was excluded from the analyses of the identification task and six participants from the analyses of the discrimination task due to poor compliance, resulting in analyzable data from 95 and 90 participants, respectively.

3.1.1 Identification task

Figure 1 represents the probability of identifying morphed faces as happy as a function of the percentage of happiness of each face along the fear-to-happiness linear continuum. Crucially, with increasing percentage of happiness, participants increasingly tended to identify the face as happy. In particular, consistent with previous evidence showing a categorical perception for morphed faces (e.g., Fugate, Gouzoules & Barrett, 2010; Jacques & Caharel, 2022), participants' identifications were fitted by a step-like function, i.e. participants were prone to identify faces as fearful up to 53.50% of happiness (CI 95% = 53.10% – 54.08%), beyond which faces were categorized as happy.

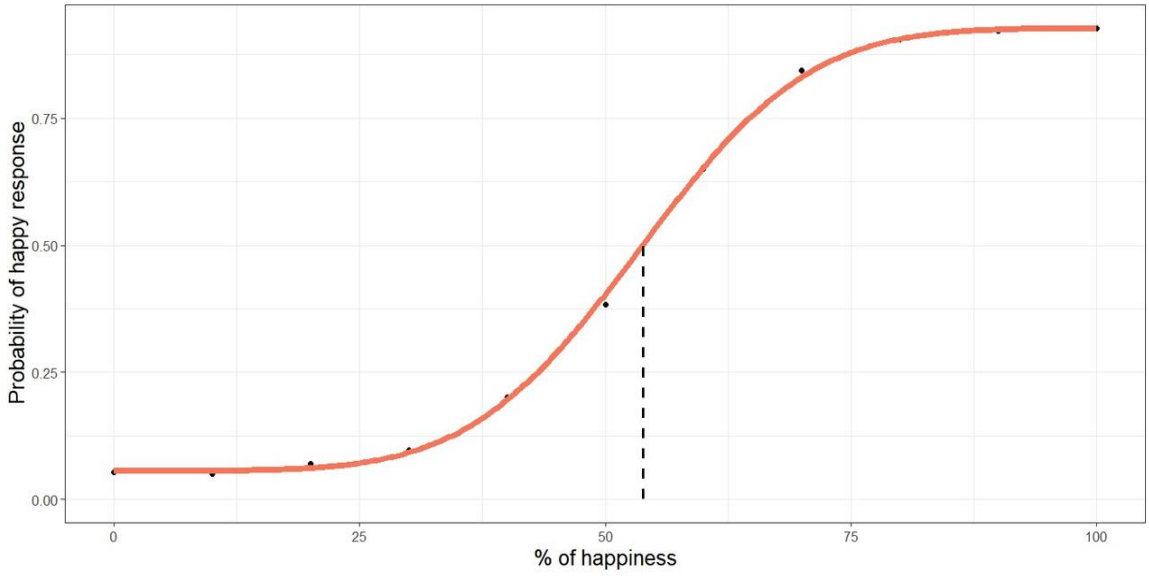


Figure 1. Participants' performance in the Identification task*. The percentage of 'happy' responses in the categorization task is plotted against the percentage of happiness along the fear-to-happiness continuum. The vertical black line delineates the point of subjective equivalence (PSE), i.e., the point along the continuum where the face was categorized as happy or fearful at chance level (0.5).*

3.1.2 Discrimination task

As the PSE estimated in the identification analysis was located at 54.13 ± 9.57 %, the between-category and within-category pairs were defined as follows: the between-category pair comprised image A morphed with 50% of happiness and image B with 70% of happiness (and the inverse combination, i.e. image A morphed with 70% of happiness and image B with 50% of happiness); the within-fear category pair was composed of image A morphed with 30% of happiness and image B morphed with 50% of happiness (and the inverse combination); the within-happiness category pair was made up by image A morphed with 70% of happiness and image B with 90% of happiness (and the inverse combination).

We observed a significant effect of AB-pair type (between-category vs. within-category) on participants' discriminative accuracy (Likelihood Ratio Test (LRT) = 28.260, $p < .0001$), being accuracy rates lower for within-category as compared to between-category pairs (beta = -.212, std. err. = .040, z-value = -5.311). For the effect of AB-pair type on participants' discriminative performance, see Figure 2 (for participants' discriminative accuracy across all AB-pairs, see Figure A1 – Appendices).

3.1.3 Correlation between categorical perception, vocabulary size and emotional intelligence

Q-Q plots assessing the normality assumption for each measure are displayed in Figure A2 – Appendices.

The slope extracted from each participant's fitted psychometric function was negatively correlated with the productive emotional vocabulary scores ($\rho = -.21$, $p = .020$ see Figure 3a), showing that the higher the PEV score, the lower the slope value and, thus, the stronger the shift in categorical perception. Moreover, there was a negative Spearman correlation between the slope and the receptive emotional vocabulary scores ($\rho = -.23$, $p = .014$; see Figure 3b), with higher VET scores associated with lower slope values.

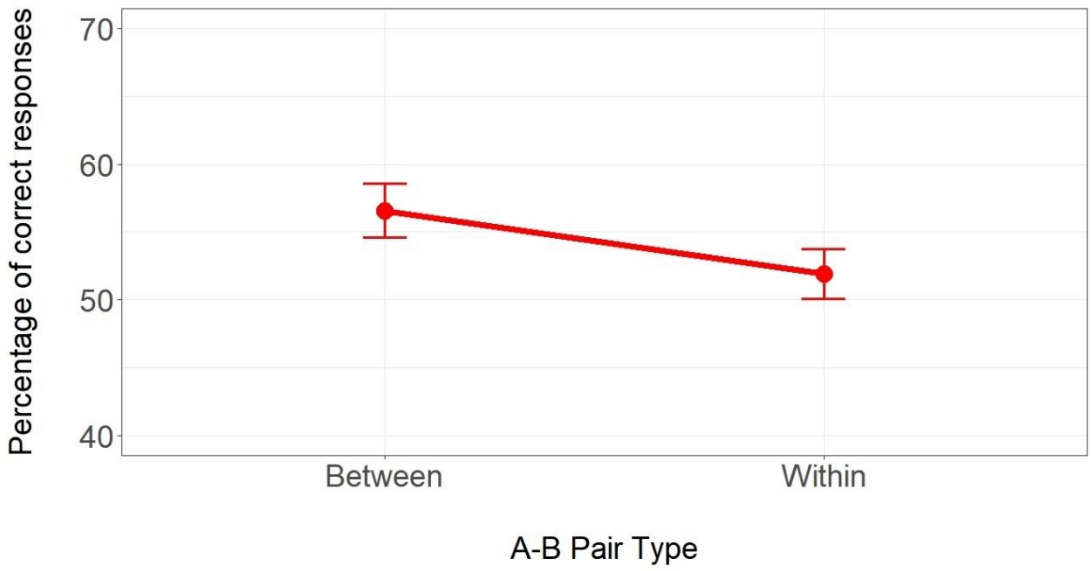


Figure 2. The Effect of AB-Pair Type on Participants' Accuracy in the Discrimination Task. *The predicted probability of correct discriminations is represented for both the between-category and the within-category pair types. Black points represent the point estimates, whereas black lines stand for the error bars.*

A negative Spearman correlation was also observed between slope values and participants' emotional intelligence total score (ρ = - .26, p = .006; see Figure 3c), meaning that higher EI scores were associated with steeper slopes.

We observed a significant positive Pearson correlation between the estimated beta coefficient in the discrimination task and participants' receptive general vocabulary scores (r = .23, p = .013 see Figure 3d), revealing that larger receptive general vocabularies were associated with bigger estimated beta coefficients for the effect of AB-pair type and, thus, to a greater between-category advantage.

No other correlation reached significance (all *ps* > .05).

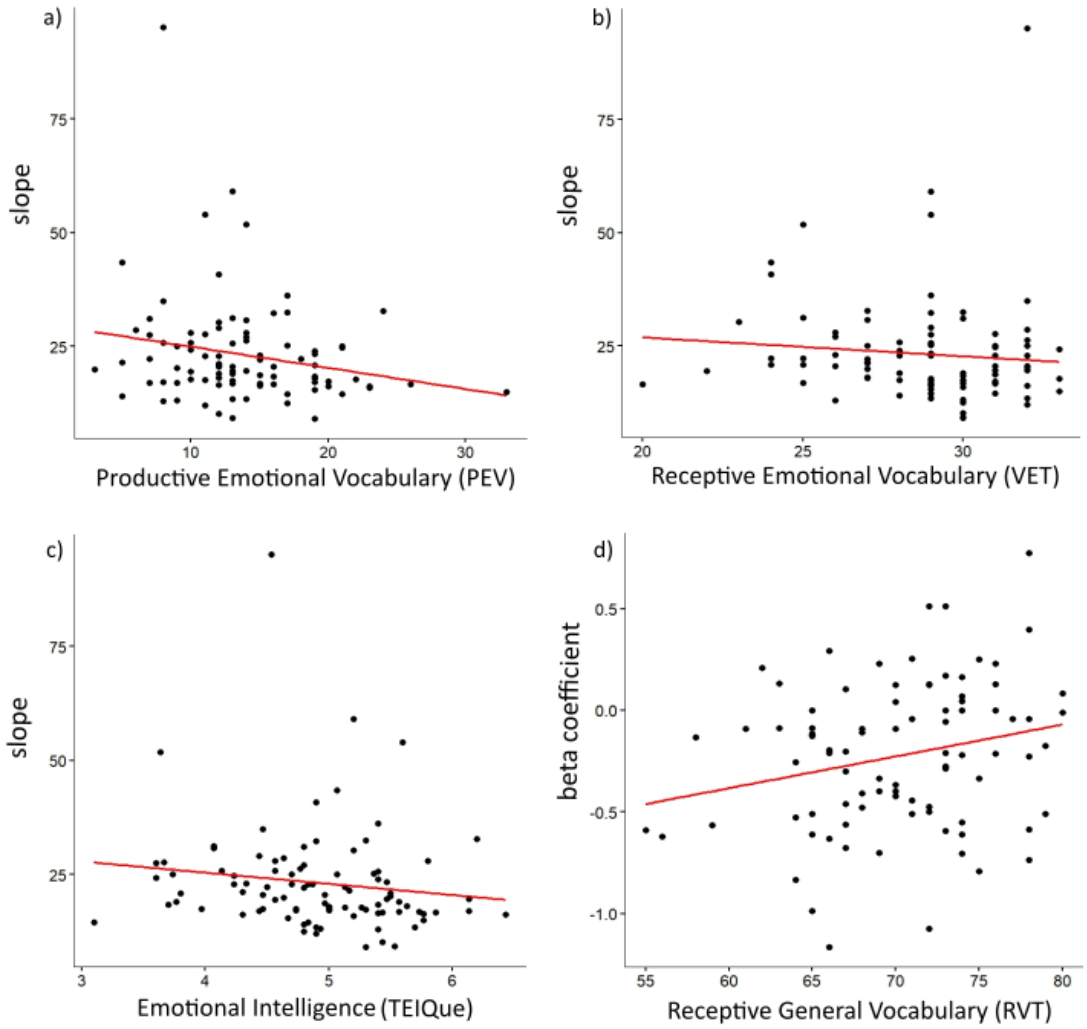


Figure 3. Relationship between categorical perception, vocabulary size and emotional intelligence*. Spearman correlations between participants' rates of change in categorical perception in the identification task, measured in terms of slope values, and (a) productive emotional vocabulary (PEV) scores, (b) receptive emotional vocabulary (VET) scores, and (c) trait emotional intelligence (TEIQue) total score; d) Pearson correlation between the estimated coefficient of the effect of AB-pair type on participants' discriminative accuracy and receptive general vocabulary (RVT) scores. Black dots represent individual points, whereas red lines stand for the regression lines.*

3.2 EXPERIMENT 2 (RESULTS)

3.2.1 Behavioral results

Two L2 words with a knowledge rate < 60% were excluded from subsequent analyses, leading to a pool of 98 neutral and 100 emotional words in the L2 condition. RTs smaller than 300 ms and greater than 2000 ms were considered outliers (e.g., Franken, Gootjes, & van Strien, 2009). Nevertheless, no trials were removed from subsequent analyses according to this criterion.

Accuracy rates were consistently high in all conditions and were thus not further analyzed.

In the RTs analysis, no significant effect was detected (all ts < 1.4, all *ps* > .1).

For what concerns affective ratings, a significant effect of Word Type on valence ratings was shown (Likelihood Ratio Test (LRT) = 375.47, $p < 0.001$, b = - 1.52, std. err. = 0.04, z = -31.03; see Figure 4a), with emotional (negative) words being perceived as less pleasant than neutral words. A significant effect of Language on valence ratings was also detected (LRT = 5.97, $p = 0.01$, b = 0.11, std. err. = 0.04, z = 2.46; see Figure 4b), being L1 words perceived as less pleasant than L2 words. The interaction between Word Type and Language did not reach significance (LRT = 0.05, $p > 0.8$). We observed a significant main effect of Word Type on arousal ratings (LRT = 327.06, $p < 0.001$, b = 1.98, std. err. = 0.07, z = 27.38; see Figure 4c), revealing that emotional (negative) words were perceived as more arousing than neutral words. No other effect reached significance (all *ps* > 0.1).

Descriptive statistics of behavioral results are reported in Table 1.

	L2 Emotional	L2 Neutral	L1 Emotional	L1 Neutral
Accuracy	98.11 ± 1.65	97.70 ± 2.06	98.33 ± 1.53	97.64 ± 1.99
RTs	706.59 ± 250.99	708.61 ± 242.16	701.75 ± 227.21	725.77 ± 252.45
Valence	2.54 ± 1.60	4.09 ± 1.17	2.29 ± 1.22	3.94 ± 0.99
Arousal	4.69 ± 1.82	2.04 ± 1.43	4.59 ± 1.77	1.99 ± 1.41

***Table 1*. Descriptive statistics of behavioral data (Experiment 2).** *Mean and standard deviation (SD) for accuracy (% correct responses), reaction times (RTs) (in ms), and valence and arousal ratings (7-point scale) in the Emotional Stroop task by Word Type (emotional, neutral) and Language (L1, L2).*

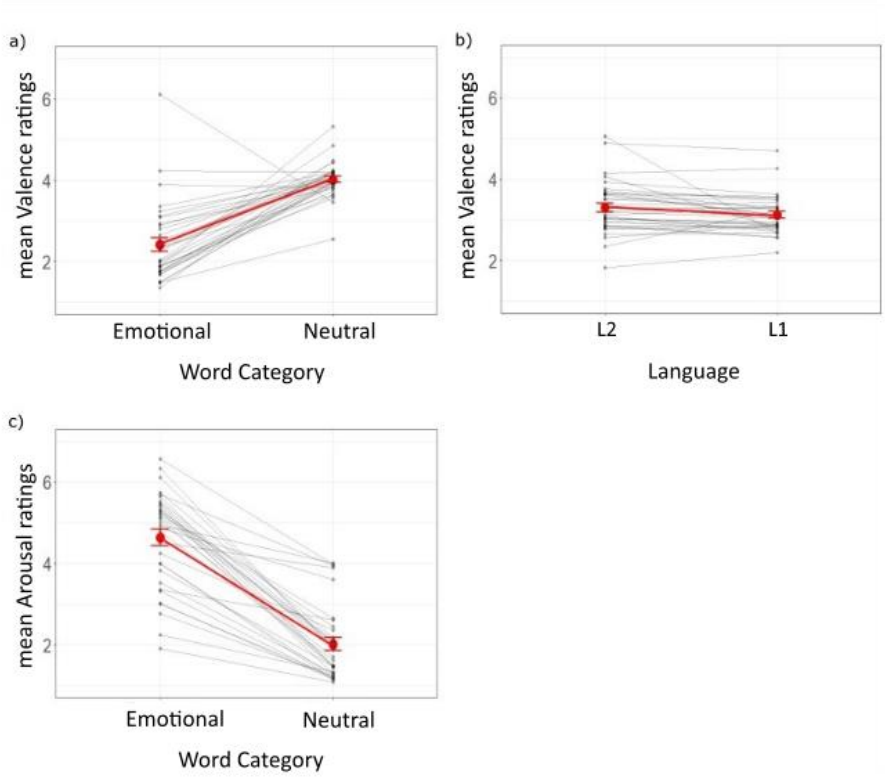


Figure 4. Language context and word category effects on participants' affective ratings. *Valence and arousal ratings (on a 7-point scale) as a function of Word Type (emotional, neutral) and Language (L1, L2). a) Mean word valence as a function of Word Type; b) Mean word valence as a function of Language; c) Mean word arousal as a function of Word Type. Black dots represent participants' individual ratings in each condition. Grey lines connect different observations from the same participant. Red dots, connected through red lines, represent the mean rating scores in the whole sample. Error bars represent standard errors. L1 = first language; L2 = second language. Figure 4 was adapted from Del Maschio et al. (2024) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.3389/fnbeh.2024.1392005).*

3.2.2 fMRI results

Three participants' fMRI data were discarded from further analyses due to excessive head motion (> 3 mm), leading to analyzable data for 33 participants.

We detected a significant main effect of Word Type, meaning that neutral (vs. emotional) words elicited stronger left-lateralized activations in the putamen, thalamus,

and sensorimotor cortex (see Table 2, Figure 5a). No significant main effect of Language emerged (p-FWE > 0.05). Significant interactions between Word Type and Language were also observed. In particular, neutral (vs. emotional) words in the L2 condition elicited a greater left-lateralized activity in the superior frontal cortex, in the sensorimotor cortex, and in the thalamus (see Table 2, Figure 5b). Furthermore, L1 (vs. L2) emotional word processing triggered greater activations in the left thalamus, in the right posterior cingulate cortex (PCC), as well as mesial and lateral aspects of the left parietal cortex (see Table 2, Figure 5c). No further contrast was significant (p-FWE > 0.05).

fMRI results are reported in Figure 5 and Table A1 - Appendices.

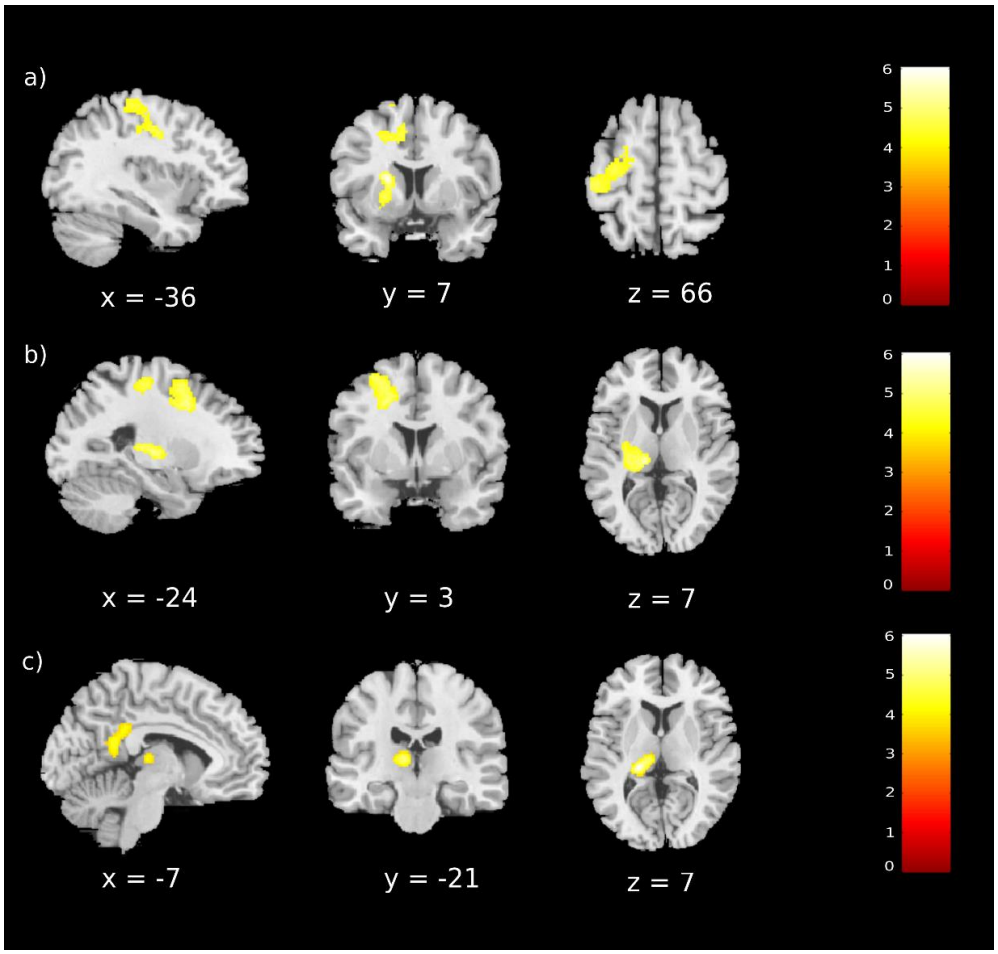


Figure 5. Contrasts leading to significant brain activations (Experiment 2). *Brain activity elicited by specific conditions at the group-level (voxel-level: p < 0.001 uncorrected; cluster-level: p-FEW < 0.05). a) Neutral words > Emotional words; b) L2 Neutral words > L2 Emotional words; c) L1 Emotional words > L2 Emotional words. Coordinates (x, y, z) are reported in MNI space. Colour bar represents t-values. Figure 5 was taken from Del Maschio et al. (2024) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.3389/fnbeh.2024.1392005).*

3.3 EXPERIMENT 3 (RESULTS)

3.3.1 Whole brain results

Seven participants were discarded from functional analyses due to excessive head motion (> 3 mm), and other seven were excluded due to low accuracies (i.e., > 2 misses or incorrect responses per emotion category in each language). Thus, data were analyzed from 38 participants. The accuracy rates of the final sample (N = 38) were almost at ceiling for all emotion categories in both languages (L1 fun = 98.68%; L1 sad = 98.25%; L1 neutral = 95.18%; L2 fun = 95.18%; L2 sad = 96.05%; L2 neutral = 91.29%).

3.3.1.1 Conjunction analyses results

In the L1 [fun vs. neutral] + L2 [fun vs. neutral] conjunction analysis, we observed significantly higher activations in a bilateral anterior temporal cluster (the left middle temporal gyrus (MTG) and the right superior temporal gyrus (STG)), in the bilateral precuneus, in a left-lateralized cluster including the inferior frontal operculum extending to the pars triangularis, and the right inferior frontal cortex.

In the L1 [sad vs. neutral] + L2 [sad vs. neutral] conjunction analysis, a significant cluster of activation was observed extending dorsally in the right hemisphere, from the middle occipital gyrus (MOG) to the superior occipital gyrus (SOG) and the superior parietal lobe (SPL). Conjunction results are displayed in Figure 6 and Table A2 – Appendices.

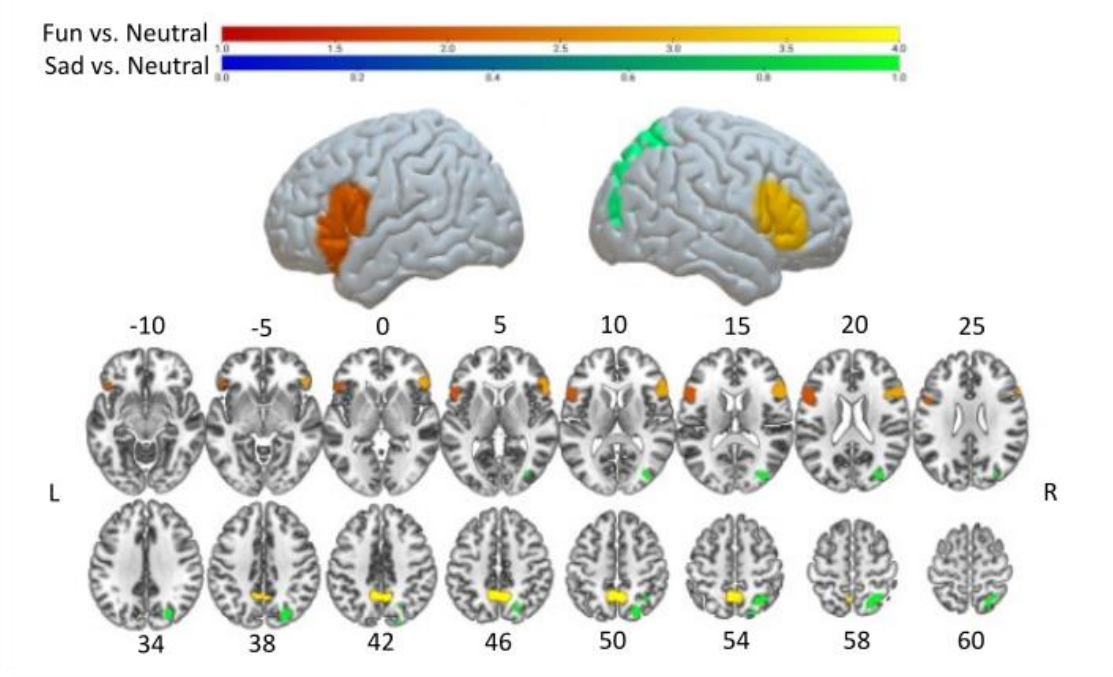


Figure 6. Overlapping brain activations across the L1 and L2 for emotionally valenced clips. *T-values for the [fun vs. neutral] conjunction are represented in red-to-yellow colors. T-values for the [sad vs. neutral] conjunction are represented in blue-to-green colors. Fun (vs. neutral) movie clips showed bilateral clusters of enhanced activation in the anterior temporal cortex (left: x = -48; y = -54; z = 12; right: x = 64; y = -44; z= 18), in the inferior frontal cortex (left: x = -52; y = 16; z = 18; right: x = 58; y = 22; z = 6), and in the precuneus (left: x = -4; y = -50; z = 46; right: x = 8; y = -54; z = 46). The processing of sad (vs. neutral) movie clips reflected in greater activity in a right-lateralized cluster peaking in the middle occipital cortex (x = 30; y = -78; z=18). R = right hemisphere; L = left hemisphere. Figure 6 was adapted from Bellini et al. (2024) (https://doi.org/10.1016/j.bandl.2024.105424).*

3.3.1.2 L1 vs. L2 contrast analyses results

For the L1 [emotional vs. neutral] vs. L2 [emotional vs. neutral] contrast, we observed two significant left-lateralized clusters in the temporal cortex, one extending from the inferior temporal gyrus (ITG) to the middle temporal cortex, and the other extending from the middle temporal cortex to the angular gyrus (Figure 7 and Table A2 – Appendices). The inverse contrast (L2 [emotional vs. neutral] vs. L1 [emotional vs. neutral]) was not significant.

Furthermore, the L1 [fun vs. neutral] vs. L2 [fun vs. neutral] contrast yielded a significant cluster of activation in the right STG (Figure 8 and Table A2 – Appendices). Any other effect failed to reach significance (all *ps* > 1).

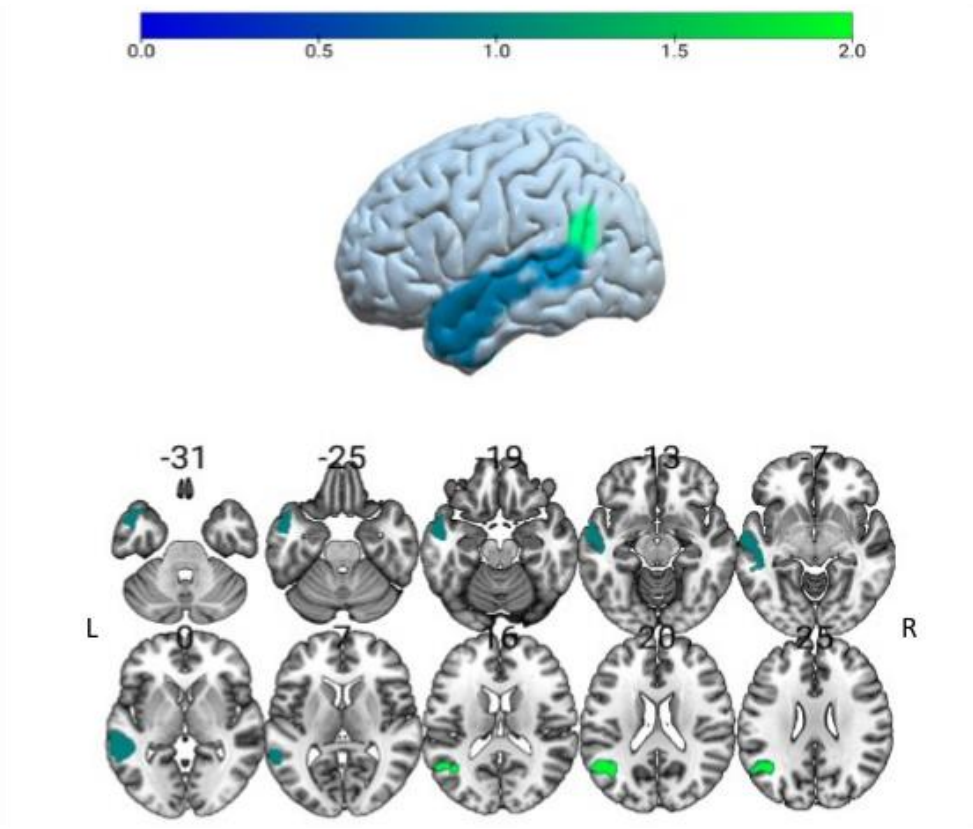


Figure 7. Brain regions showing enhanced activation for emotionally valenced clips presented in the L1 vs. L2. *The colorbar represents t-values for the L1 [emotional vs. neutral] vs. L2 [emotional vs. neutral] contrast. Emotionally charged movie clips presented in L1 vs. L2 led to greater activations in two left-lateralized clusters localized in the left temporal cortex, one peaking in the inferior temporal gyrus (x = -44; y = -2; z = -44) and extending to the middle temporal cortex (x = -60; y = -12; z = -10), the other peaking in the middle temporal cortex (x= -46; y = -56; z= 20) and extending to the angular gyrus (x = -38; y = -58; z = 24). L = left hemisphere; R = right hemisphere. Figure 7 was adapted from Bellini et al. (2024) (https://doi.org/10.1016/j.bandl.2024.105424).*

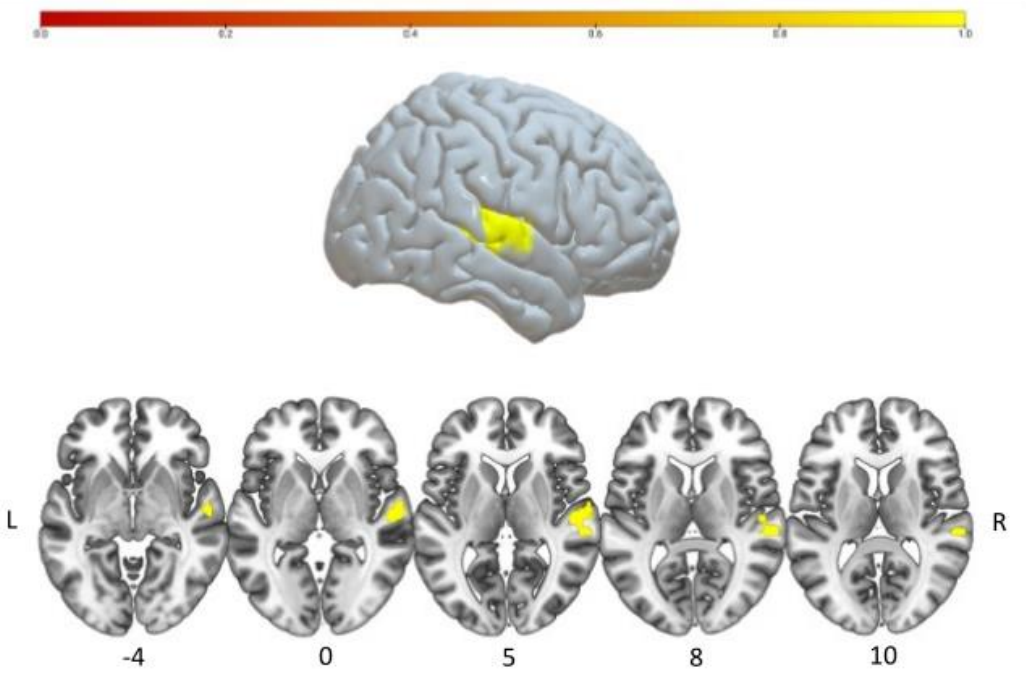


Figure 8. Brain regions showing enhanced activity for positively valenced clips presented in the L1 vs. L2. *The colorbar represents t-values for the L1 [fun vs. neutral] vs. L2 [fun vs. neutral] contrast. The processing of fun movie clips presented in L1 vs. L2 reflected in enhanced activity in the right superior temporal cortex (x = 58; y = -28; z= 8). L = left hemisphere; R = right hemisphere. Figure 8 was adapted from Bellini et al. (2024) (https://doi.org/10.1016/j.bandl.2024.105424).*

3.3.2 ROI analyses results

The contrast estimates extracted from the right amygdala between L1 [emotional vs. neutral] and L2 [emotional vs. neutral] showed a trend towards significance (t = 1.9965, std. dev. = 1.1962, p = .053). However, the contrast estimates for L1 [fun vs. neutral] were significantly higher than those for L2 [fun vs. neutral] in the right amygdala (t = 3.181, std. dev = .753, p = .003). Crucially, the difference in contrast estimates extracted from the left amygdala for the same contrast [fun vs. neutral] were not significant (t = 1.909, std. dev. = .902, p = .064). No other difference reached significance (all *ps* > .2).

3.3.2.1 Correlation between amygdala response and bilinguals' language experience

We detected a significant positive correlation between the L2 [fun vs. neutral] contrast estimate extracted from the right amygdala and participants' L2 objective

proficiency (ρ = .480, p = .002), with higher L2 proficiency levels associated with greater signals extracted from the right amygdala for fun movie clips (see Figure 9). No other significant correlation reached significance (all ps > .4).

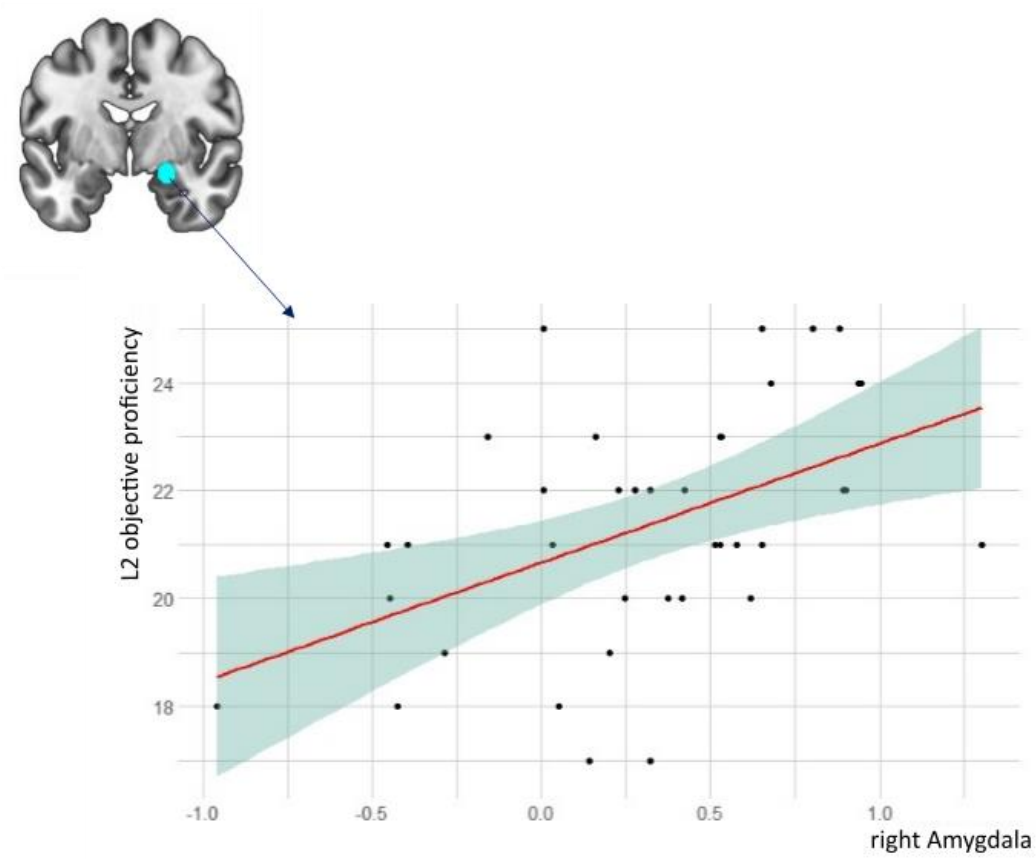


Figure 9. Correlation between L2 proficiency and right amygdala response to positively valenced clips. *The scatterplot displays the Pearson correlation value between the estimate extracted from the right amygdala (x) for the L2 [fun vs. neutral] contrast and second language (L2) proficiency (y). Figure 9 was adapted from Bellini et al. (2024) (https://doi.org/10.1016/j.bandl.2024.105424).*

3.4 EXPERIMENT 4 (RESULTS)

3.4.1 Between-group analysis

For each moral dilemma, significant effects of language condition are represented separately for each dependent variable.

Moral decisions (binary responses). The effect of language condition on moral decisions reached significance in the *Bike Week* dilemma ($\chi^2(1) = 4.62$, $p = 0.03$, beta = 0.65, std. err. = 0.30, z = 2.13), revealing that using a L2 increased the rate of utilitarian responses. In particular, 28.12% of participants decided to harm the biker when the dilemma was presented in the L1, whereas this percentage increased to 42.85% when it was presented in the L2. No other effect reached significance, neither in the *Surgeon* ($\chi^2 = 2$, $p > 0.1$) nor in the *Factory* dilemmas ($\chi^2 < 1$, $p > 0.4$).

Norm judgments (rating scales). A significant effect of language condition was detected on participants' permissibility ratings in both the *Bike week* (beta = 0.36, std. err. = 0.13, t = 2.82, $p = 0.004$) and the *Surgeon* (beta = 0.36, std. err. = 0.12, t = 2.42, $p = 0.015$) dilemmas, with higher permissibility ratings associated with the use of the L2 vs. the L1. No significant effect was observed in the *Factory* dilemma ($t < 1$, $p > 0.8$).

Emotional distress (rating scales). No significant effect of language condition on perceived emotional distress reached significance (all *ps* > 0.2).

Figure 10 represents the proportion of utilitarian responses, mean permissibility ratings, and mean emotional distress ratings as a function of language condition, for each moral dilemma.

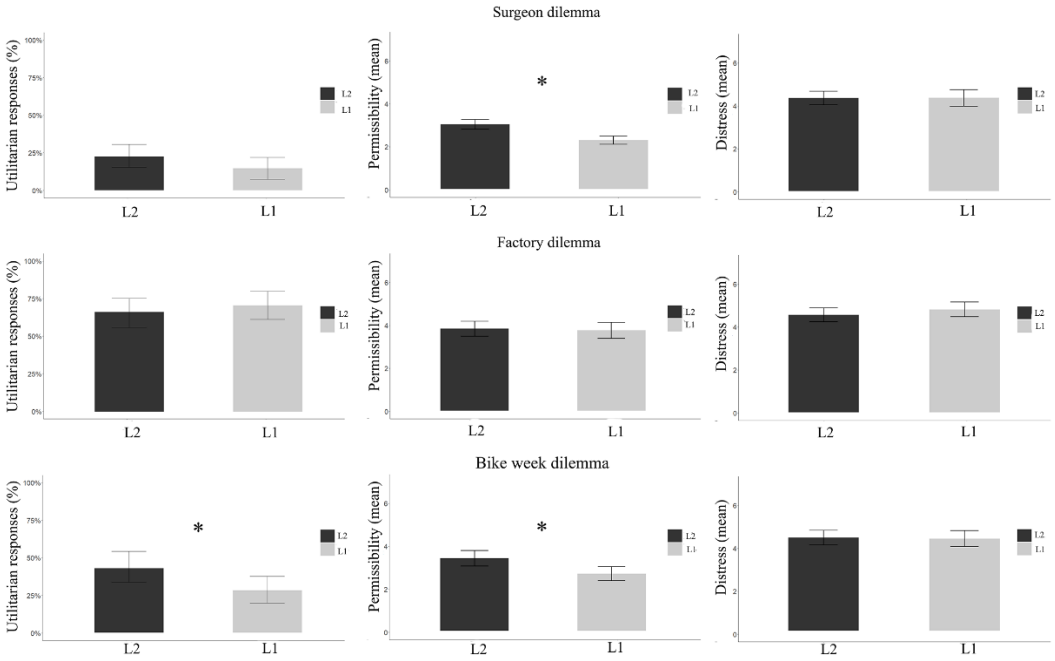


Figure 10. Effects of language context on participants' moral decisions, norm judgments and emotionality. *The percentage of utilitarian responses (left panels), the mean permissibility of the moral violation (central panels), and the mean emotional distress (right panels) are reported for each scenario (A = Surgeon, B = Factory, C = Bike week) and for language condition (L1 = first language – N = 98; L2 = second language – N = 96). Significant differences between language conditions are marked with an asterisk (p < 0.05). Figure 10 was adapted from Del Maschio et al. (2022b) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.1017/langcog.2022.14).*

3.4.2 Within-group analysis

Moral decisions (binary responses). In the *Surgeon* dilemma, a significant the three-way interaction between L2 proficiency, Language Dominance, and L2 AoA was observed ($\chi^2(1) = 8.296$, $p = 0.003$, beta = 1.43, std. err. = 0.68, z = 2.08; see Table A3 - Appendices). To better inspect the interaction, we divided participants into early (i.e., L2 AoA ≤ 6, $N = 39$) and late bilinguals (i.e., L2 AoA > 6, $N = 59$). As shown in Figure 11, the moral choices of early and late bilinguals display (almost) opposite patterns. In early bilinguals, the probability of utilitarian responses increased with increasing L2 proficiency when the dominance ratio was low, whilst the same probability decreased with decreasing L2 proficiency when the dominance ratio was high. In late bilinguals, the probability of utilitarian responses decreased with decreasing L2 proficiency when the

dominance ratio was low, whilst utilitarian responses were constantly low when the dominance ratio was high.

No significant effect of L2 background on participants' moral decisions emerged neither in the *Bike Week* nor in the *Factory* dilemmas.

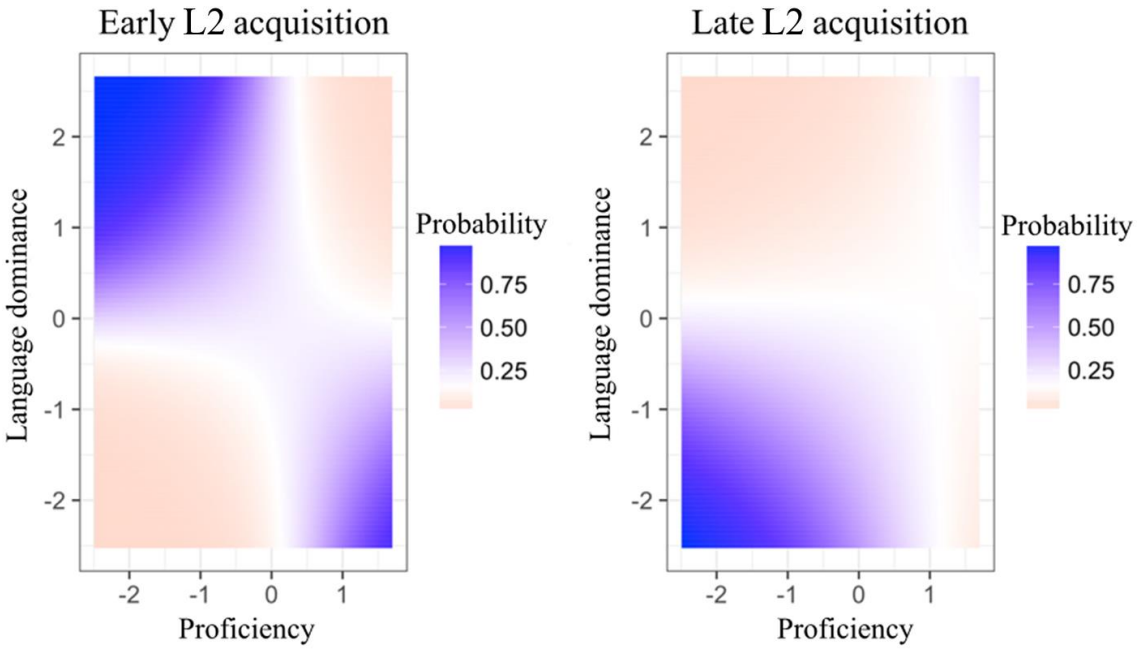


Figure 11. Effects of L2 background on participants' utilitarian responses in the Surgeon dilemma. *Panel (A) and (B) show the language dominance × FL proficiency interaction for early and late bilinguals, respectively. Bilinguals within the 1st and the 4th quantile were selected to represent early and late bilinguals. The values represent the probability predicted by the statistical model. The axes display centered predictors. Figure 11 was adapted from Del Maschio et al. (2022b) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.1017/langcog.2022.14).*

Norm judgments (rating scales). In the *Bike Week* dilemma, a significant two-way interaction between L2 AoA and Language Dominance ($\chi^2(1) = 4.383$, $p = 0.03$, beta = 0.47, std. err. = 0.22, t = 2.07; see Table A8 - Appendices) was detected. To further inspect the interaction, participants were divided into early (i.e., L2 AoA ≤ 6, $N = 39$) and late bilinguals (i.e., L2 AoA > 6, $N = 59$). As shown in Figure 12b, early bilinguals were slightly more willing to judge the moral violation as permissible, when the dominance ratio was high. In late bilinguals, the pattern was the same, but slightly more marked. Moreover, we observed a significant two-way interaction between L2 Proficiency and Language Dominance ($\chi^2(1) = 3.95$, $p = 0.04$, beta = 0.30, std. err. = 0.15, t = 1.95; see

Table A8 - Appendices). To further inspect the interaction, the 1st and the 4th quantile of L2 Proficiency were used to split participants into low and high proficient bilinguals. As shown in Figure 12c, highly proficient bilinguals more likely rated the moral violation as permissible when Language dominance was high, whereas in low proficient bilinguals the probability to judge the action as forbidden increased with increasing Language dominance.

In the *Surgeon* dilemma a significant two-way interaction between L2 Proficiency and L2 AoA was observed ($\chi^2(1) = 4.288$, $p = 0.03$, beta = 0.45, std. err. = 0.21, t = 2.06). The interaction was explored by splitting participants into early (i.e., L2 AoA ≤ 6, N = 39) and late bilinguals (i.e., L2 AoA > 6, N = 59). As shown in Figure 12a, in early bilinguals, the perceived permissibility of the depicted moral violation increased with increasing L2 proficiency; in late bilinguals, with increasing the probability to judge the action as forbidden increased whilst the probability to judge the action as obligatory decreased.

No effect reached significance in the *Factory* dilemma.

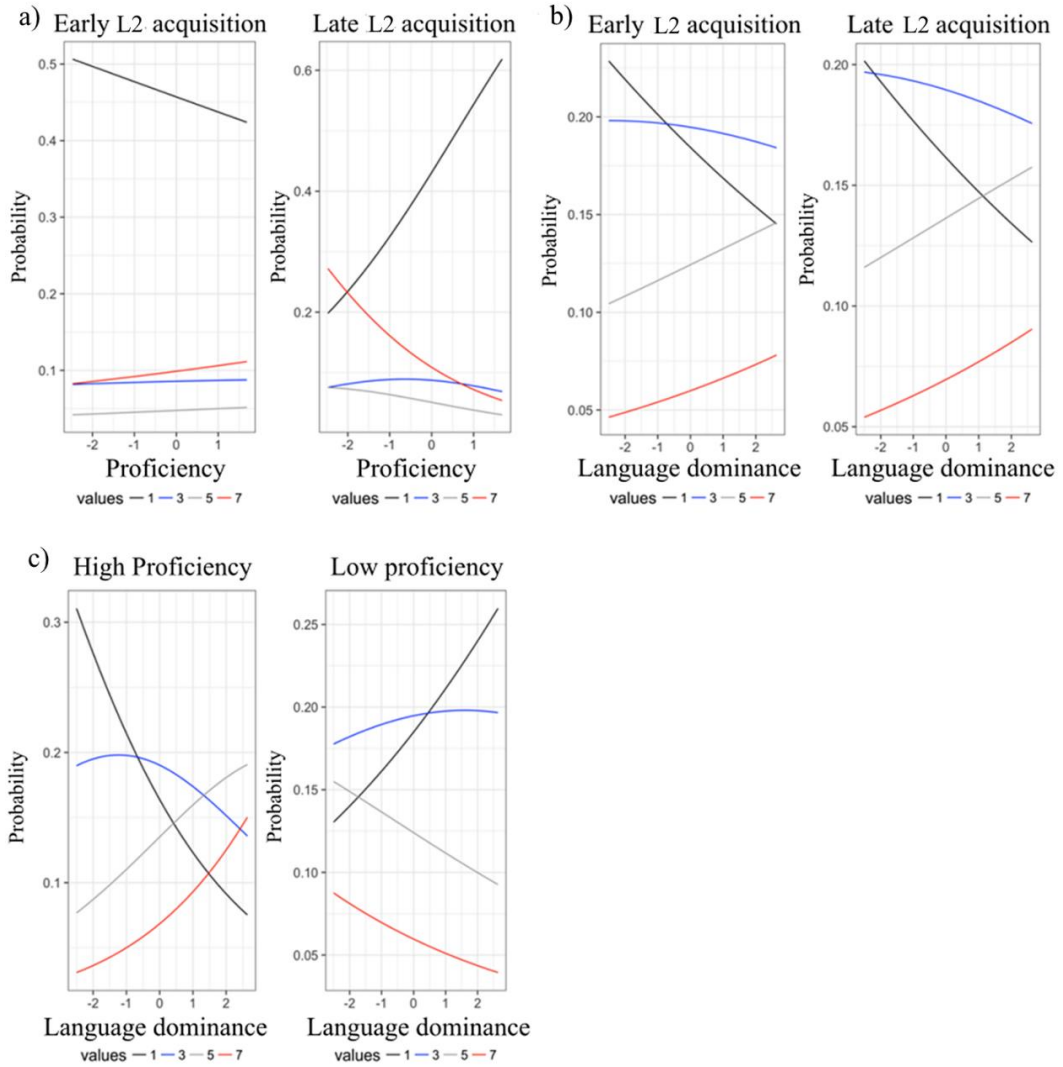


Figure 12. Effects of L2 background on participants' permissibility ratings of moral violations. *Panel (a) represents the L2 AoA × L2 Proficiency interaction in the Surgeon dilemma. Panel (b) represents the L2 AoA × Language Dominance interaction in the Bike week dilemma. Panel (c) represents the L2 Proficiency × Language Dominance interaction in the Bike week dilemma. Bilinguals within the 1st and the 4th quantile of L2 AoA were selected to represent early and late bilinguals, respectively. Bilinguals within the 1st and the 4th quantile of L2 Proficiency were selected to represent low and high proficient bilinguals, respectively. The values represent the probability predicted by the statistical model. Different lines represent predicted probabilities for different representative values of the permissibility scale. The x-axis displays the centered predictor. Figure 12 was adapted from Del Maschio et al. (2022b) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.1017/langcog.2022.14).*

Emotional distress (rating scales). In the *Bike week* dilemma, the interaction between L2 AoA and Language Dominance was significant ($\chi^2(1) = 108.74$, $p = 0.005$, beta = 0.46, std. err. = 0.16, t = 2.75). In late bilinguals, the perceived emotional distress was higher

with increasing dominance ratio, whereas in early bilinguals the emotional distress rapidly decreased for higher Language dominance values (see Figure 13b).

In the *Factory* dilemma, the interaction between L2 AoA and Language Dominance proved to be significant ($\chi^2(1) = 97.377$, $p = 0.005$, beta = 0.44, std. err. = 0.15, t = 2.77). Late bilinguals showed higher emotional distress ratings with increasing Language dominance, whereas early bilinguals' emotional distress ratings were lower with increasing Language dominance (see Figure 13a). Moreover, a main effect of L2 Proficiency was observed ($\chi^2(1) = 96.273$, $p = 0.009$, beta = 0.46, std. err. = 0.17, t = 2.56), with higher emotional distress ratings for higher L2 proficiency values.

No significant effect was detected for the *Surgeon* dilemma.

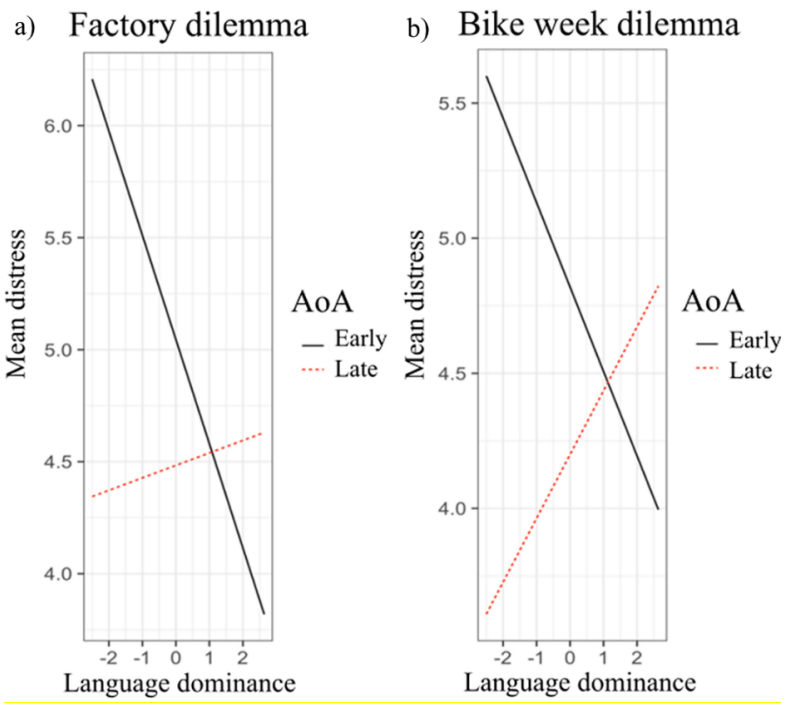


Figure 13. Effects of L2 background on participants' perceived emotional distress. *Panel (a) shows the effects of L2 AoA and Language Dominance on perceived distress in the Factory dilemma. Panel (b) represents the effects of L2 AoA and Dominance ratio on perceived distress in the Bike week dilemma. Bilinguals within the first and the fourth quantile were selected to represent early and late bilinguals, respectively. Lines represent values predicted by the statistical model. The x-axis displays the centered predictor. Figure 13 was adapted from Del Maschio et al. (2022b) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.1017/langcog.2022.14).*

3.5 EXPERIMENT 5 (RESULTS)

3.5.1 Between-group analysis

3.5.1.1 Moral dilemmas

For each moral dilemma, we reported any significant effect of language context and problem condition independently for each dependent variable.

Moral decisions (binary responses). The effects of language context or problem condition on participants' moral decisions failed to reach significance, both in the *Bike week* dilemma (all *ps* > .05) and in the *Surgeon* dilemma (all *ps* > .1).

Norm judgments (rating scales). In the *Bike week* dilemma, we observed a significant effect of language context on participants' permissibility ratings (χ^2= 4.932, *p* = .026), revealing that the prospected moral violation was judged as more acceptable in the L2 vs. L1, irrespective of problem condition (beta = .431, std. err. = .195, t = 2.215). No other effect was significant, neither in *Bike week* (all *ps* > .3) nor *Surgeon* (all *ps* > .4).

Emotional distress (rating scales). In the *Bike week* dilemma, main effects of both language context (χ^2= 374.29, *p* = .012) and problem condition (χ^2= 372.90, *p* = .026) on participants' perceived emotional distress were significant, with decreased emotional distress in the L1 (vs. L2) context (beta = -.478, std. err. = .190, t = -2.522) and uncertain (vs. certain) conditions (beta = -.422, std. err. = .190, t = -2.227). No other effect was significant (all *ps* > .1).

For the proportion of moral responses, the mean permissibility ratings, and the mean emotional distress ratings as a function of language context and problem condition, see Figure 14.

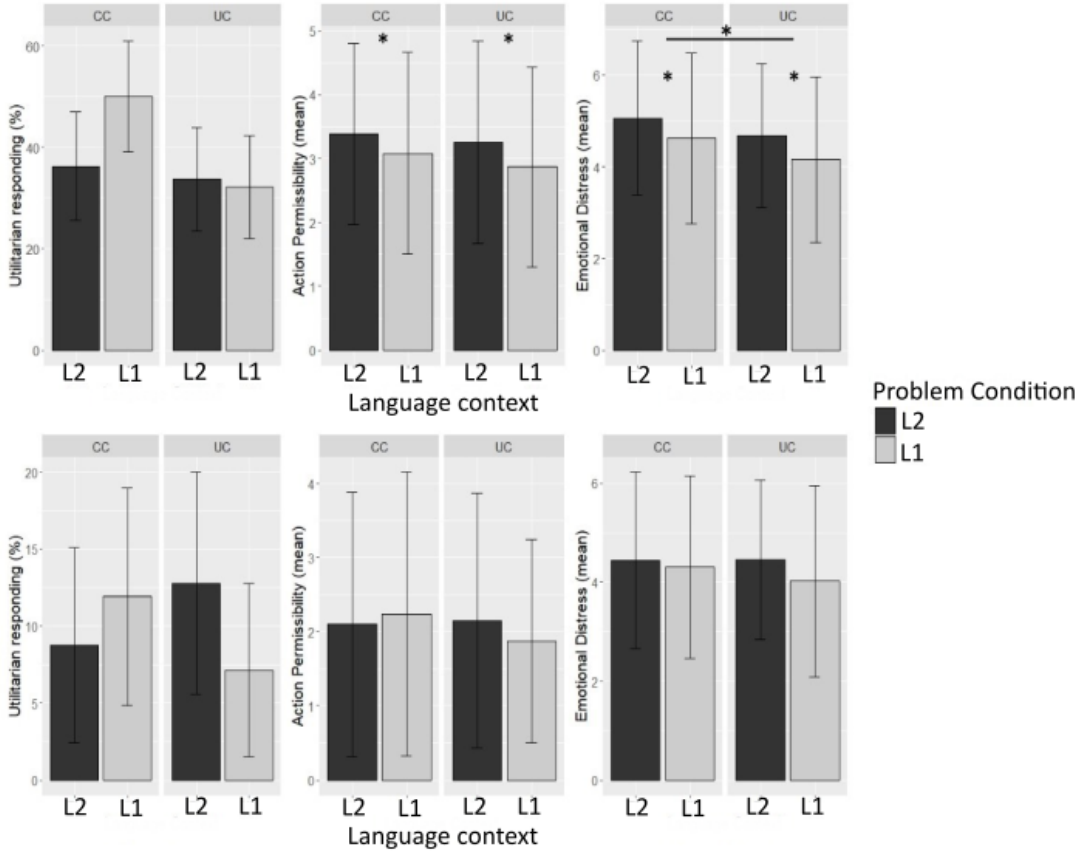


Figure 14. Effects of language context and problem condition on participants' moral decision making and perceived emotional distress. *For each moral dilemma (Bike Week on top, Surgeon on bottom), the percentage of utilitarian responses (left panels), the mean permissibility of moral violations (central panels), and the mean emotional distress ratings (right panels) are reported as a function of language context (L1 = first language; L2 = second language) and problem condition (CC = certainty condition; UC = uncertainty condition). Error bars represent the standard error of the mean. Significant differences between language contexts and problem conditions are marked with an asterisk ($p < 0.05$). Figure 14 was adapted from Del Maschio et al. (submitted).*

3.5.1.2 Exploration-exploitation problems

Exploration vs. exploitation choices (binary responses). Language context did not exert a significant effect on participants' choices, neither in the *Oil drilling company* problem ($\chi^2(1) = 2.950$, p = .086), nor in the *Broken glass* problem ($\chi^2(1) = .096$, $p = .757$).

Emotional distress (rating scales). Language context significantly influenced participants' distress ratings in both *Oil drilling company* ($\chi^2(1) = 262.37$, $p < 0.0001$) and *Broken glass* ($\chi^2(1) = 254.74$, $p < 0.0001$), with decreased emotional distress in the L1

(vs. L2) context in both problems (*Oil drilling company*: beta = - .741, std. err. = .157, t = -4.724; *Broken glass*: beta = - .618, st.err. = .157, t = -3.943).

For the proportion of explorative choices and the mean emotional distress ratings as a function of language context, see Figure 15.

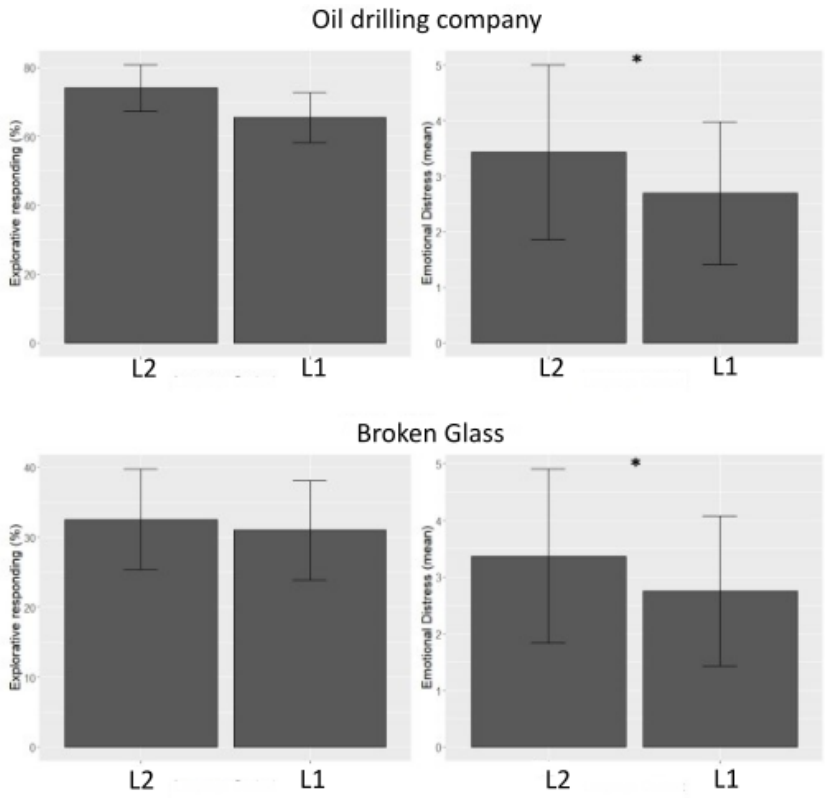


Figure 15. Effects of language context on participants' choices and perceived emotional distress in explorative-exploitative problems. *For each exploration-exploitation problem (Oil drilling company on top, Broken Glass on bottom), the percentage of exploratory responses (left panels) and the mean emotional distress ratings (right panels) are reported as a function of language context (L1 = first language; L2 = second language). Significant differences between language conditions are marked with an asterisk (p < 0.05). Figure 15 was adapted from Del Maschio et al. (submitted).*

3.5.2 Within-group analysis

3.5.2.1 Moral dilemmas

For each moral dilemma, we reported any significant effect of L2 background independently for each dependent variable. When differences between problem conditions (CC vs. UC) were detected, we statistically tested their reliability.

Moral decisions (binary responses). In the certain version of *Bike week* (CC), no effect of L2 background on participants' moral decisions was significant (all *ps* > .2). Nevertheless, in the uncertain version of *Bike week* (UC), the three-way interaction between L2 proficiency, L2 exposure, and L2 immersion was significant ($\chi^2(1) = 5.687$, p =.017, beta = -22.9, std. err. = 20.152, z = -1.136; see Table A12 - Appendices). To further inspect the interaction, we used the 1st and 3rd quantiles of L2 proficiency to divide participants into low and highly proficient bilinguals. As shown in Figure 16, the two proficiency groups an almost opposite pattern of moral choices. Indeed, in low proficient bilinguals, the probability of utilitarian responses increased with increasing exposure when L2 immersion was high, whilst the same pattern was less pronounced when immersion was low. In highly proficient bilinguals, the probability of utilitarian choices decreased with increasing exposure when immersion was high, whereas the same probability increased with increasing exposure when immersion was low. To test for possible differences between the certain vs. uncertain versions, problem condition was entered as an additional predictor in the model. The three-way interaction between L2 proficiency, L2 exposure, and L2 immersion was still significant ($\chi^2(1) = 6.393$, p = .011, beta = -10.418, std. err. = 6.246, z = -1.668; see Table A13 – Appendices). The pattern was identical to the one described immediately above. No other significant effect emerged (p > .1).

In the certain version of *Surgeon* (CC), no significant effect of FL background on participants' moral decisions was observed (CC) (p > .1). However, in the uncertain version of *Surgeon* (UC), the main effect of L2 exposure was significant ($\chi^2(1) = 5.112$, p = .024), showing that the probability of utilitarian responses increased as exposure increased (beta = 3.692, std. err. = 1.599, z = 2.308). No other effect was significant (all χ^2 < 1, all *ps* > .1). Entering problem condition as a further predictor in the model, the significant effect of L2 exposure on participants' moral decisions was still detected ($\chi^2(1)$ = 6.672, p = .001), with a pattern identical to the previous analysis.

Norm judgments (rating scales). In both versions of Bike week (CC, UC), no effect of L2 background on participants' permissibility ratings reached significance (all *ps* > .1).

In the certain version of *Surgeon* (CC), no significant effect of L2 background emerged (all *ps* > .05). Though, in *Surgeon* (UC), a significant effect of L2 exposure was observed ($\chi^2(1) = 6.305$, $p = .012$), with lower permissibility ratings for higher L2 exposure values (beta = 2.853, std. err. = 1.13, t = 2.524). Entering problem condition as a further predictor in the model, a significant effect of exposure on participants' permissibility ratings was observed ($\chi^2(1) = 7.959$, $p = .005$), paralleling the previous analysis.

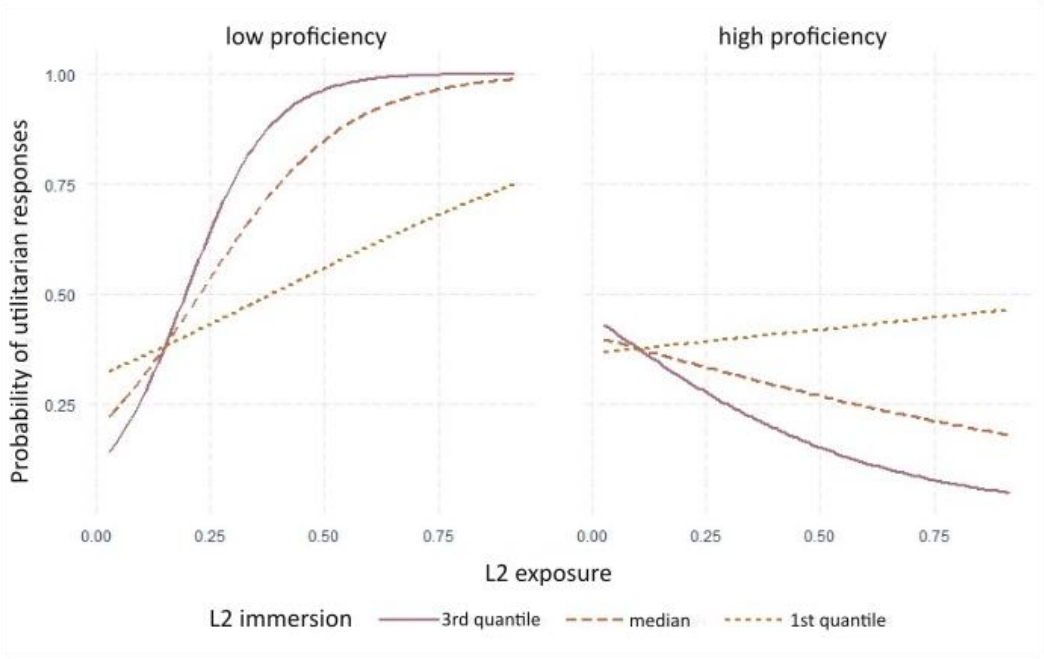


Figure 16. Effects of L2 background on participants' utilitarian responses in the Bike week dilemma under conditions of uncertainty. *The three-way interaction between L2 exposure and L2 immersion on bilinguals' probability of utilitarian responses is shown for low proficient participants (1st quantile of the proficiency measure) and highly proficient participants (3rd quantile of the proficiency measure). Values represent the probability of utilitarian responses predicted by the statistical model. The L2 immersion predictor is represented as scaled. Figure 16 was adapted from Del Maschio et al. (submitted).*

Emotional distress (rating scales). In both versions of *Bike week* (CC, UC), no significant effect of L2 background on participants' emotional distress was observed (all *ps* > .1).

In *Surgeon* (CC), no significant effect of L2 background was detected (all *ps* > .1). In the uncertain version of *Surgeon* (UC), a three-way interaction between L2 proficiency, L2 exposure, and L2 immersion was proved to be significant ($\chi^2(1) = 62.342$, $p = .049$,

beta = - 3.775, std. err. = 2.007, t = -1.881; see Table A14 – Appendices). The interaction was further inspected by using the 1st and 3rd quantiles of L2 proficiency to split participants into low and highly proficient bilinguals. In the low proficient group, the emotional distress steadily decreased with increasing immersion when the L2 exposure was low, while it tended to be rather constant with increasing immersion when exposure was high. In the high proficient group, the emotional distress increased with increasing immersion for higher values of exposure, being the same pattern even more marked when exposure was low. Adding problem condition as a further predictor in the model, a significant effect of exposure on emotional distress was observed ($\chi^2(1) = 144.96$, $p = .033$), indicating that emotional distress decreased with increasing exposure (beta = -1.844, std. err. = .864, t = -2.133).

3.5.2.2 Exploration-exploitation problems

Exploration vs. exploitation choices (binary responses). In *Oil drilling company*, a simple effect of L2 proficiency on participants' choices was found ($\chi^2(1) = 4.643$, $p = .031$), revealing that the probability of explorative choices increased for higher proficiency levels (beta = .094, std. err. = .044, z = 2.127). In *Broken glass*, the two-way interaction between L2 proficiency and L2 immersion was significant ($\chi^2(1) = 5.061$, $p = .024$), showing that, when immersion was high, the probability of exploratory choices increased with increasing proficiency, whilst it decreased for lower proficiency levels (beta = 1.356, std. err. = .631, z = 2.149; see Table A15 – Appendices).

Emotional distress (rating scales). In *Oil drilling company*, a significant effect of L2 proficiency was observed ($\chi^2(1) = 141.50$, $p = .006$), revealing that the higher the proficiency level, the lower the perceived emotional distress (beta = -.083, std. err. = .030, t = -2.771). Also in the *Broken glass* problem, the effect of L2 proficiency reached significance ($\chi^2(1) = 135.12$, $p = .001$), with higher proficiency levels associated to lower emotional distress ratings (beta = - .098, std. err. = .029, t = -3.382).

3.5.3 Further analyses

We further explored the significant effects of L2 background observed in previous analyses in interaction with cognitive style (CRT) and risk-taking (PID-5) measures.

3.5.3.1 Reflective thinking (CRT score)

Moral decisions (binary responses). In *Bike week* (UC), we entered the CRT score as a further predictor in the final model including the three-way interaction between L2 proficiency, L2 exposure, and L2 immersion. The three-way interaction between bilingual measures was still significant ($\chi^2(1) = 10.715$, $p = .001$, beta = -38.001, std. err. = 27.038, z = -1.405). In addition, we observed a significant three-way interaction between L2 proficiency, L2 immersion, and CRT score on moral decisions ($\chi^2(1) = 9.816$, $p = .002$, beta = -3.834, std. err. = 1.538, z = -2.492; see Table A16 - Appendices). To further inspect the interaction, we split data for low (i.e., 1st quantile) and high (i.e., 3rd quantile) CRT scores. For participants with lower CRT scores, the probability of utilitarian responses increased linearly with immersion, independently of the proficiency level attained in the L2. For participants with higher CRT scores, the probability of utilitarian responses increased with immersion when proficiency was low, whilst the same probability decreased with immersion when proficiency was high (see Figure 17).

In *Surgeon* (UC), we entered the CRT score as a further predictor in the final model including a main effect of L2 exposure. A two-way interaction between L2 exposure and CRT scores on moral decisions emerged ($\chi^2(1) = 6.167$, $p = .013$; see Table A17 – Appendices), showing that the probability of utilitarian responding increased with a S-shape curve with increasing exposure for higher CRT scores, whereas the same probability steadily decreased with exposure for lower CRT scores (beta = 6.236, std. err. = 3.354, z = 1.860). No other modulatory effect of cognitive style was significant (all *ps* > .1).

In exploration-exploitation problems, no modulatory effect of cognitive style reached significance (all *ps* > .1).

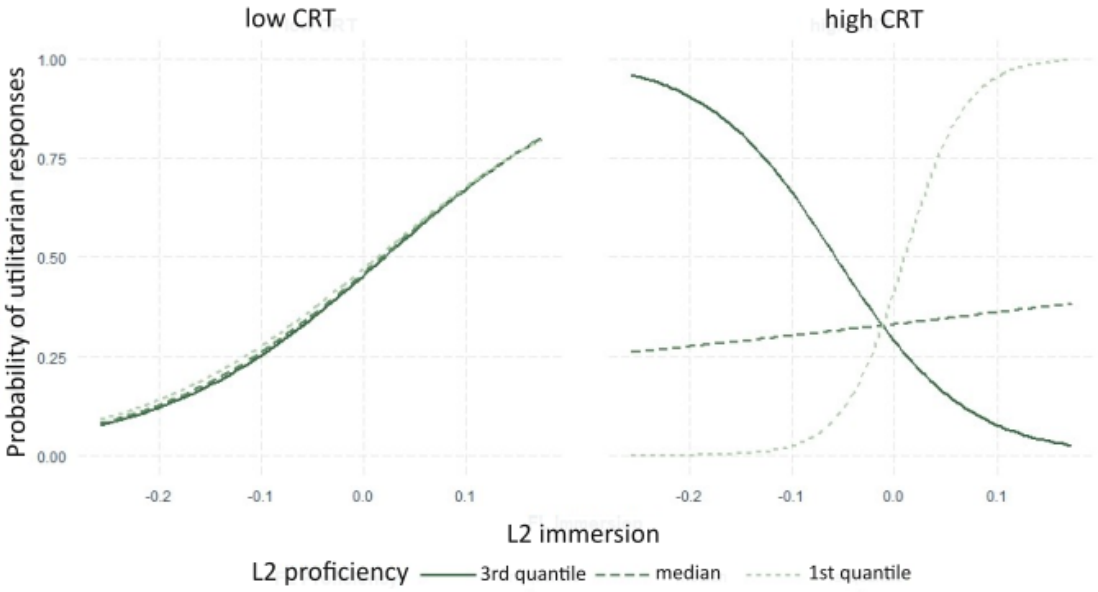


Figure 17. Effects propensity toward reflective thinking (CRT score) on bilinguals' utilitarian responses in the Bike week dilemma under conditions of uncertainty. *The three-way interaction between L2 immersion and L2 proficiency on participants' utilitarian responses is shown for participants with low propensity toward reflective thinking (1st quantile of the CRT score, left panel) and high propensity toward reflective thinking (3rd quantile of the CRT score, right panel). The L2 immersion and the L2 Proficiency predictors are represented as scaled. Figure 17 was adapted from Del Maschio et al. (submitted).*

3.5.3.2 Risk taking attitude (PID-5)

3.5.3.2.1 Moral dilemmas

Moral decisions (binary responses). In *Bike week* (UC), the PID-5 score was included as a further predictor in the final model including the three-way interaction between L2 proficiency, L2 exposure, and L2 immersion[5]. The interaction was no longer significant ($\chi^2(1) = 2.273$, $p = .132$). Neither modulatory effects of risk-taking attitude nor any other effects reached significance (all $ps > .1$).

Emotional distress (rating scales). In *Surgeon* (UC), we entered the PID-5 score as a further predictor in the final model including the three-way interaction between L2 proficiency, L2 exposure, and L2 immersion. The interaction was no longer significant ($\chi^2(1) = 58.424$, $p = .319$). However, we found a significant three-way interaction between L2 proficiency, L2 exposure, and PID-5 score on distress ratings ($\chi^2(1) = 58.601$, $p = .012$,

[5] The logistic regression model was fitted using Firth's bias reduction method, to overcome the problem of complete separation, by means of the logistf package (Heinze, Ploner, & Jiricka, 2022).

beta = -.09, std. err. = .037, z = -2.426; see Table A18 – Appendices). To further inspect the interaction, we split participants into low (i.e., 1st quantile of the PID-5 score) and high risk-taking (i.e., 3rd quantiles of the PID-5) profiles. In participants with a low risk-taking attitude, the emotional distress slightly increased with exposure for lower proficiency levels, whereas it slightly decreased with exposure for higher proficiency levels. The opposite patterns observed for low and high proficiency levels were even more marked for participants with a high risk-taking attitude. No other modulatory effect of risk-taking attitude was significant (all *ps* > .1).

3.5.3.2.2 Exploration-exploitation problems

Exploration vs. exploitation choices (binary responses). In *Broken glass*, we added the PID-5 score as a further predictor in the final model including the two-way interaction between L2 proficiency and L2 immersion. The interaction was still significant ($\chi^2(1) = 4.519$, $p = .034$, beta = 1.337, std. err. = .655, z = 2.042). Moreover, a significant two-way interaction between immersion and PID-5 scores on participants' choices emerged ($\chi^2(1) = 3.933$, $p = .047$; see Table A19 – Appendices). In participants with high risk-taking attitude, the probability of exploration choices increased with increasing immersion, whereas in participants with low risk-taking attitude the same probability steeply decreased with increasing immersion (beta = .644, std. err. = .331, z = 1.947). No other modulatory effect of risk-taking attitude was observed (all *ps* > .1).

4 DISCUSSION

The nature of the relationship between language and emotion has long been debated, with some suggesting a limited role for language in emotion (e.g., Ekman, 1992) and others emphasizing a constitutive role for language in emotion (e.g., Barrett, 2006a). However, a great deal of evidence suggests that emotions are perceived and experienced differently from individual to individual, both within the same culture and belonging to different cultures, casting doubt on all those perspectives that support the universality of emotions. Such variability has been explained by arguing that emotions are mental states arising from domain-general psychological elements, among which emotion conceptual knowledge which is supported by language (e.g., Lindquist & Gendron, 2013). Emotion conceptual knowledge is defined as a storage containing all emotional instances that an individual has acquired either through direct experiences or by learning through others (Lindquist, 2013). Crucially, as these modal instances are highly different from each other, words would help to bind them together into a single category. Such developed categories would in turn shape human perception and experience of emotions (as well as speech sounds, objects, colors, and so on; Lupyan et al., 2020). Consistently, Experiment 1 shows that previously developed categories lead to categorically perceived continuously varying emotions from faces. Furthermore, our results highlight that interindividual differences in both general and emotion conceptual knowledge correspond to different emotion perception, with broader vocabularied leading to more defined perceptions. Therefore, the use of different words to group different instances into categories affects both the content and application of conceptual knowledge of emotions, leading to corresponding differences in emotion perception and experience. Accordingly, a considerable intercultural variability in the meaning and experience of emotions has been reported (e.g., Crivelli et al., 2016a; Gendron et al., 2014; Jackson et al., 2019). Thus, many studies examined emotional processing in bilinguals at the behavioral level, with mixed results. Yet bilinguals' emotional processing has been little investigated at the neural level. Experiments 2 and 3 aimed at filling this gap in bilingual literature, exploring the neural correlates of processing emotionally charged words and movie clips, respectively. Experiment 2 showed that, in spite of null behavioral effects, processing emotional words in the L1 vs. L2 led to enhanced brain activity in the posteromedial cortex associated with emotional processing (e.g., Rolls, 2019), suggesting an increased

emotional resonance for words presented in a bilingual's first language. However, numerous limitations plague previous research (including Experiment 2), among which the qualitative conceptualization of bilingualism adopted, and the myriads of different tasks used (especially with isolated stimuli). In Experiment 3, implementing a naturalistic viewing paradigm and a continuous approach to bilingualism, we found evidence for a greater involvement of brain regions involved in semantic processing for emotional movie clips presented in the L1 vs. L2, suggesting a greater language-dependent conceptual retrieval. Additionally, emotional movie clips presented in the L1 (vs. L2) recruited to a larger extent the amygdala, a key region of emotional processing, highlighting deeper emotional reactions to such stimuli. Notably, the response of the amygdala to emotional movies presented in the L2 increased with increasing proficiency in the second language, suggesting a native-like processing of emotional stimuli for those who attained higher levels of proficiency. Quantifying such differences in emotions according to the language in which they are processed is crucial as emotions are thought to influence our cognition and behavior. In particular, Experiments 4 and 5 evaluate both language context (i.e., L1 vs. L2) and bilingualism-related (e.g., AoA, proficiency, language dominance, etc.) effects on moral decision making and judgment. Results showed a dilemma-specific FLE, suggesting that it is the peculiar content of each scenario that eventually triggers a more utilitarian (or deontological) inclination when deciding in a L2. Moreover, in both experiments, a different decision making in a bilingual's two languages was not driven by a reduced emotionality in the L2, but instead by a dampened access to normative knowledge. Furthermore, the adoption of a continuous approach to bilingualism allowed us to observe nuanced complex effects of bilingualism on decision making, stressing the need to re-define current conceptualizations of the FLE. Within this chapter, in the following sections, a broader discussion of the results of each experiment is provided, along with a concluding general discussion.

4.1 EXPERIMENT 1 (DISCUSSION)

In recent decades, constructionist accounts of emotion language have proposed that language, through emotion conceptual knowledge, support the construction of emotion. Experiment 1 thus intended to evaluate the association between conceptual knowledge,

in terms of both general and emotional vocabulary, and emotion perception from faces. Results showed that participants displayed CP for morphed emotional faces, suggesting that previously acquired emotion categories shape the perception of continuously varying facial configurations. Of note, associations between size of participants' vocabulary and CP for emotional faces were found, indicating that a more structured conceptual knowledge corresponds to a more defined emotion perception. Furthermore, CP was more pronounced in participants with a higher trait emotional intelligence, pointing to a consistency between emotion perception abilities and self-perceived emotional abilities.

4.1.1 Emotions are categorically perceived

Participants' identification data were fitted by a step-like function, in which the probability of identifying each morphed face as happy increased with an increasing percentage of happiness. Specifically, participants categorized all morphed faces containing up to 53.50% of happiness as fearful and all other morphs exceeding that percentage as happy. Therefore, stimuli that varied continuously along the "only fear"-to-"only happiness" dimension seemed to be perceived discreetly, as sorted into groups. Such claim was further strengthened by the findings of the discrimination task, attesting the distinctive between-category advantage. Participants were indeed more likely to accurately discriminate whether the target image was identical to image A or image B when these source images crossed the categorical boundary as compared to when they fall within the same category. Morphed faces that were identified by participants as belonging to different emotion categories were more easily segregated, increasing the probability of correctly matching the target image, whereas those categorized both as fearful or happy were harder to differentiate, lowering participants' accuracy at chance levels. Of note, image A and image B were always separated by the same physical distance, being two-steps apart along the "only fear"-to- "only happiness" continuum. Therefore, in line with previous studies (e.g., Calder et al., 1996; Campanella et al., 2015; Jacques & Caharel, 2022; McCullough & Emmorey, 2009), we found evidence for CP of morphed emotional faces in both the identification and the discrimination task. Early studies (e.g., Calder et al., 1996; de Gelder, Teunisse & Benson, 1997) tentatively attributed CP to the structural configuration of the face, consistently with basic emotion views claiming that discrete emotion categories are reliably encoded in specific facial muscle movements and, thus, easily decoded from the face. Contrary to this structural

hypothesis (e.g., Ekman, 1992), a conceptual account (Barrett, Lindquist & Gendron, 2007) imputes CP to the emotion conceptual knowledge accessed to make meaning of undefined sensory inputs as instances of discrete emotions in a given context. For instance, in the study of Fugate, Gouzoules and Barrett (2010) described in section 1.3.3, CP was shown to take place when participants learnt to match labels to unfamiliar Chimpanzee facial expressions, leading the authors to conclude that facial configurations *per se* were not sufficient. Accordingly, we believed that the CP we observed for morphed emotional faces was driven by emotion words that directed participants' perception of continuous stimuli into discrete categories, anchoring their judgments. Indeed, as morphed emotional faces do not encode the "prototypical" facial expression of each emotion, it seems plausible that emotion words, rather than the disrupted structural information, led participants to categorically perceive emotions from faces.

4.1.2 The relationship between general and emotion conceptual knowledge and CP of emotion

Consistently with our hypothesis, a wider vocabulary knowledge was found to correspond to a stronger categorical perception of morphed emotional faces. In particular, the rate of change in perception, as measured by the slope steepness of the fitted psychometric function, was found to entertain significant negative correlations with both productive and receptive emotion vocabulary sizes. Lower values of the slope imply stronger shifts in categorical perception, whereas higher values of the slope reveal weaker perceptual transitions from one category to the other. Thus, the observed negative associations seem to suggest that participants with a broader emotional vocabulary showed a more abrupt perceptual shift from fear to happiness, sorting continuously varying stimuli into groups with shaper boundaries. Furthermore, the discrepancy in accuracy rates between within-category pairs and between-category pairs, operationalized by the beta coefficient estimated for the effect of AB-pair type in generalized linear models, positively correlated with receptive general vocabulary size. A bigger beta coefficient stands for a greater accuracy for within-category as compared to between-category pairs, revealing an enhanced between-category advantage. Hence, the positive correlation we found would suggest that participants with a wider receptive general vocabulary displayed a more pronounced categorical perception of morphed emotional faces. In particular, they would be more likely to group continuous stimuli into

previously formed categories, maximizing between-category variability and minimizing differences among instances belonging to the same category. Our results of a relationship between vocabulary size and emotion perception are consistent with previous developmental evidence of a strong relationship between language skills and emotional competence (e.g., Bosacki & Moore, 2004; Bruce, Ermanni & Bell, 2024; Ornaghi & Grazzani, 2013). Most studies have extensively used vocabulary size, operationalized as the number of known words, as a measure of language ability. Strong associations between receptive vocabulary and several components of emotional competence (e.g., Bosacki & Moore, 2004; Cutting & Dunn, 1999; Streubel et al., 2020) have been systematically found. Notably, these findings have been interpreted in light of the role of language in supporting the acquisition and access to conceptual knowledge about emotions (Cole, Armstrong, & Pemberton, 2010). Indeed, as highlighted in section 1.3.2, words are thought to drive the acquisition of conceptual categories, allowing to learn that different instances belong to the same category by bringing attention to their common distinctive features and overshadowing the irrelevant ones. Accordingly, the development of conceptual knowledge might sustain the acquisition of defined emotion concepts, allowing the transition from a valence-based to a categorial perception of emotions (Nook et al., 2017). Additionally, emotional competence has been found to entertain a positive association with emotion-specific vocabulary (e.g., Beck et al., 2012; Ornaghi & Grazzani, 2013; Streubel et al., 2020), suggesting that emotion-specific language might allow a deeper conceptual understanding of emotion. Findings obtained from the identification data fitted with this claim, suggesting that wider emotion vocabularies might provide a relevant contribution when categorizing emotional faces. We tentatively hypothesize that the emotion words used in the identification task to anchor participants' categorization (i.e., "fear" and "happiness") more directly prompted the access and retrieval of conceptual knowledge about emotions to interpret indefinite emotional faces in terms of a distinct emotion category. Accordingly, participants' performance in the identification task would tap to a greater extent on emotion-specific vocabulary knowledge, with a more differentiated emotion vocabulary presumably facilitating participants' conceptualization of specific emotions. On the other hand, a better performance in the discrimination task was found to correspond to a larger general receptive vocabulary size. As mentioned in section 1.6, the hallmark of CP is the between-

category advantage, which exploits the maximization of between-category differences and the minimization of within-category variability. Crucially, such function is thought to be carried out by the words that refer to earlier developed categories. Our discriminative results thus seem to support this claim, as participants with a larger number of words in their general knowledge vocabularies showed a greater difference between stimuli crossing the categorical boundary and stimuli within the same category, with a significantly better performance for the former. Surprisingly, emotion vocabulary size was not found to be significantly associated with participants' between-category advantage, presumably because matching a target face to either source in absence of explicit emotion labels recruit to a greater extent domain-general, rather than emotion-specific, knowledge.

4.1.3 The relationship between trait emotional intelligence and CP of emotion

Participants' identification of morphed emotion faces was significantly associated also with trait EI scores. In particular, participants who self-perceived better their emotional abilities also showed a sharper shift in perception from *fear* to *happiness* when categorizing morphed emotion faces. Trait EI refers to people's perceptions and beliefs about their own emotional abilities (Petrides & Furnham, 2001). It has been increasingly evidenced that, regardless of their accuracy, self-perceptions strongly affect many aspects of human life, including cognition and mental health (Bandura, 1997; Bouffard et al., 1998; Zell & Krizan, 2014; for a meta-analysis, see Freund & Kasten, 2012). Indeed, self-perceived abilities have been systematically shown to entertain low-to-moderate correlations with actual abilities (Aesaert et al., 2015, 2017; Cai, Viljaranta & Georgiou, 2018; Chuang, Wu & Wang, 2019). Of note, self-perceived emotional abilities have been found to influence real emotional competence (Jeckeln, Mamassian & O'toole, 2022, 2023; Sinvani & Fogel-Grinvald, 2024; but see, for instance, Fisher, Kret & Broekens, 2018). For instance, Petrides and Furnham (2003) presented participants with an identification task in which morphing faces progressed sequentially from a neutral to one of six prototypical expressions. Participants with higher trait EI scores identified the expressions faster, and also needed fewer frames, than those with lower trait EI, leading the authors to suggest that emotional dispositions shape emotion recognition abilities. Additionally, trait EI has been shown to predict several affective outcomes such as facial emotion recognition (Andrei et al., 2015). Therefore, our results highlighting an

association between trait EI and perception of morphed emotion faces are consistent with such previous evidence. Accordingly, participants with higher self-reported emotional competence also displayed a sharper discrete categorization of undefined emotional stimuli. Nevertheless, it is worth noting that, being correlational, such evidence cannot provide information about the direction of this association. Indeed, an accurate recognition of others' emotional experiences might or update or originate from self-perceived emotional intelligence.

4.1.4 Conclusions

Our findings show that the perception of emotion faces is affected by language, as humans tend to perceive continuously varying stimuli through the lens of previously acquired categories. Such categories would shape perception by maximizing inter-category differences and minimizing intra-category variability. Crucially, this function is thought to be carried out by the words stored in conceptual knowledge, which would allow to learn that different instances belong to the same category emphasizing the characteristic features and overcasting the irrelevant ones. Words are thus thought to be particularly relevant for the acquisition of emotion categories, leading people to associate a given instance with the phonological sound of a word (Barrett and Lindquist, 2008; Vigliocco et al., 2009; Borghi and Binkofski, 2014). Accordingly, a strong relationship between vocabulary size, an index of language skills, and emotional competence has been systematically attested throughout development. As evidence of the relationship between language skills and emotional competence derived from developmental studies focusing mostly on early and middle childhood, our findings provide insights on the evolution of such association in adulthood. Therefore, we found evidence supporting the constructionist view of emotion, as a larger conceptual knowledge corresponded to a sharper conceptualization of undefined emotional faces into discrete categories. Moreover, our results well support the constructionist prediction of an interindividual variability in emotion perception and experience.

4.1.5 Limitations of the study

Due to the correlational nature of the study, we were able to assess the magnitude of the relationship between vocabulary knowledge and emotion perception from faces but not the direction of that association. Based on the wealth of research of the effects of

language on perception and the growing evidence of the role of vocabulary on the development of emotional skills in childhood and adolescence, we interpreted our findings as supporting the active role of language in emotion through the development of conceptual knowledge. Yet we cannot rule out the possibility that developed emotional skills also contribute to vocabulary knowledge growth, further contributing to the observed relationship. Consequently, future studies should focus more on the nature of this relationship in adulthood, further establishing its direction.

4.2 EXPERIMENT 2 (DISCUSSION)

In the previous study we found evidence of a close association between language and emotion, showing that interindividual differences in conceptual knowledge correspond to a different perception of emotion from faces. The current study explored the effect of using a first vs. second language on conceptual knowledge on emotion, assessing the behavioral and neural correlates of the effects of using different languages on emotion perception and experience. To this aim, an emotional interference task (i.e., the EST) was administered to participants while acquiring functional data in the MR scanner. As already mentioned, emotional processing in a bilingual's two languages is still an open research field with no clear-cut answers. In spite of many behavioral studies conducted on bilinguals' processing of emotional information, neuroimaging evidence is still scarce. Hence, Experiment 2 aimed at advancing knowledge on the neural underpinnings of bilinguals' emotional processing. Behavioral data did not show any emotional interference effects neither in the L1 nor in L2, arguably due to the reduced asymmetry in proficiency and use between the two languages in our participants. Nevertheless, functional data revealed that processing emotional information in L1 (vs. L2) led to stronger activations in subdivisions of the posteromedial cortex associated with attention modulation, episodic memory, and emotional processing.

4.2.1 Behavioral results

Behavioral data revealed that participants processed words similarly in their languages. Crucially, these findings are consistent with previous evidence of no difference in emotional word processing in a bilingual's two languages (e.g., Ahn & Jiang, 2023;

Eilola et al., 2007; Sutton et al., 2007; Grabovac & Pléh, 2014). Such observations would suggest that processing emotional stimuli in an L2 is as automatic as that in an L1. Accordingly, the similar emotional effects emerged in the EST between the participants' two languages could temptingly be attributed to the fact that the participants were relatively balanced in terms of language proficiency and exposure. Yet, the aforementioned studies found an Emotional Stroop effect of comparable size in L1 and L2, that is increased response times for emotional as compared to neutral words, irrespective of the language in which they were presented. On the contrary, we failed to observe an interference of negative (vs. neutral) words on participants' performance in either language. As reported in section 1.4.2, the emotional content of words is irrelevant to perform the EST, which relies on an automatic implicit processing of stimuli. For instance, Crossfield and Damian (2021) found a significant processing advantage for positive words over negative and neutral words in the LDT (i.e., an explicit task), whereas null effects in the EST. The authors thus concluded that significant effects of valence would be limited to tasks where this variable is relevant for task success, and/or tasks requiring a deeper level of processing. Accordingly, as explicit (vs. implicit) tasks have been suggested to enhance emotional processing, capturing participants' top-down attention more promptly, the absence of an Emotional Stroop effect may be attributed to the shallower level of processing at which the task operates (Liao & Ni, 2021). This claim seems to be further supported by affective ratings completed after the EST, showing that negative words were perceived as less pleasant and more arousing than neutral words. Furthermore, L1 words were overall rated as less pleasant than L2 words. The different word processing mechanisms implied in implicit and explicit tasks (i.e., affective rating) would be responsible for the task-specific effects observed here and in previous studies. Indeed, whereas the EST requires participants to overlook the words' content to identify the ink color, affective ratings would make participants allocate, to a larger extent, attentional resources on word meanings.

4.2.2 fMRI results

In spite of null behavioral effects, we observed a significant word processing difference between the two languages at the neural level. Processing differences between emotional and neutral stimuli have been consistently reported both at the psychophysiological and neural level (e.g., Compton et al., 2003; Fan et al., 2016; Harris,

Ayçiçeği & Gleason, 2003; Thomas et al., 2007). Our functional data are consistent with such previous evidence, arguably because behavioral and hemodynamic responses show a different sensitivity to the emotional content of words across a bilingual's two languages. Specifically, L1 versus L2 emotional words were found to trigger greater activations in areas of the posteromedial cortex associated with attention modulation, episodic memory, and emotional processing. The posteromedial cortex receives major inputs from the dorsal visual stream and somatosensory areas, as well as from areas with emotion- and social-related functions, including the subgenual ACC and the orbitofrontal cortex (Rolls, 2019). Furthermore, the ventral sectors of the PCC and the adjacent retrosplenial cortex are interconnected with the medial temporal lobe involved in memory functions (Leech & Sharp, 2014; Vogt et al., 2001). Indeed, the PCC has been systematically shown to be activated in tasks involving the modulation of attentional focus (e.g., Hahn et al., 2007; Pearson et al., 2011), episodic memory (see, Rugg & Vilberg, 2013), the recall of emotionally salient contextual information (e.g., Maratos et al., 2001), and the evaluation of emotional versus neutral verbal stimuli (e.g., Maddock et al., 2003).

Whereas our behavioral findings revealed no difference in emotionality between the two languages, fMRI results suggest an increased emotional resonance for words presented in a first language. Crucially, previous behavioral and psychophysiological studies showed a modulatory role of L2 proficiency on the amount of difference in emotional resonance between the L1 and L2 (e.g., Caldwell-Harris et al., 2011; Champoux-Larsson & Nook, 2024; Degner et al., 2012; Ferré et al., 2010). Our behavioral findings appear to align with this claim, as all participants were highly proficient in their L2 and relatively balanced with respect to the use of the two languages at time of testing. Accordingly, their high proficiency levels may have leveled out any differences in word processing between the two languages. Nevertheless, the effect of language on word processing observed at the neural level would highlight the modulatory influence of other dimensions of bilinguals' language background, such as learning context. According to the emotional context of learning hypothesis (Caldwell-Harris, 2014; Harris et al., 2006), when L2 is acquired in formal contexts (e.g., classrooms), its semantics would not grow on emotional experiences to the same extent of the semantic representation of L1, thus leading to a reduced emotionality in L2. Indeed, our participants were raised in Italy

where Italian is dominantly spoken and learnt English mostly in instructional settings. The increased emotional response to negative stimuli in L1 (vs. L2) may be thus ascribed to the deeper emotional resonance associated with that language, acquired in a context grounded in emotional experiences.

Additionally, we did not observe any significant effect of word type or interaction between word type and language in the amygdala, a key region for emotional processing (LeDoux, 2000). Indeed, the amygdala has been found to be activated especially in tasks requiring an explicit evaluation of the emotional content of words (Chen et al., 2015). Moreover, brain circuits involved in emotional processing have been shown to respond to a greater extent to pictures than words, presumably because the former are perceived as more biologically salient and arousing than the latter. For instance, in a recent meta-analysis of fMRI data on implicit emotional processing in monolinguals (Feng et al., 2021), affective pictures and words were shown to be differently processed, and to activate different neural systems, with only negative pictures reliably recruiting the amygdala. Accordingly, in Experiment 3 the amygdala was found to be activated also for emotionally charged movie clips, which are known to trigger intense emotional reactions (see section 3.3.2).

4.2.3 Conclusion

We investigated the neural correlates of emotional processing in a bilingual's two languages, by administering the color-word variant of the Emotional Stroop task (EST) to a sample of highly proficient and relatively balanced bilinguals, who learnt their L2 mostly in non-immersive contexts (i.e., instructional settings). Behavioral data did not show a different sensitivity to emotional words between the first and the second language, arguably due to the characteristics of our sample in terms of attained proficiency and exposure to L2, which would have leveled any difference in emotional resonance between the two languages. Nevertheless, functional data revealed a greater sensitivity to emotional words in L1 versus L2 in posteromedial brain regions dedicated to attention, memory recall, and socioemotional processing, suggesting an increased emotional resonance associated with processing words in the first language. As through fMRI we captured emotionality effects that were not behaviorally detectable with the EST, we

encourage future research aiming at exploring bilinguals' emotional processing and control to implement more suitable tasks.

4.2.4 Limitations of the study

This study suffers from some limitations that are worth mentioning. First, we did not directly assess the effects of bilingual language background on our bilingual participants' emotional processing, thus any statement about their role is merely speculative. Moreover, our participants were required to respond manually through key presses. Response modality has been shown to modulate the magnitude of the Stroop interference, with generally smaller effects in variants requiring manual (vs. verbal) responses (e.g., Augustinova, Parris & Ferrand, 2019; Kinoshita, Mills & Norris, 2018; Scaltritti, Job & Sulpizio, 2022). Third, although our study increased knowledge on the neural basis of bilingual emotional processing, the use of isolated, decontextualized affective words does not ecologically mirror bilinguals' processing of affective stimuli in real-life.

4.3 EXPERIMENT 3 (DISCUSSION)

To overcome the latter limitation of the previous study, in Experiment 3 we explored in a more ecological manner the neural correlates of emotional processing in a bilingual's two languages. To this aim, in the MR scanner participants were presented with a naturalistic viewing paradigm such as watching original (L2) vs. dubbed versions (L1) of emotional movie clips. We observed that processing emotional movie clips in L1 (vs. L2) led to enhanced activations in the lateral temporal cortex, suggesting a deeper semantic-related processing involved in the interpretation of dynamic sensory stimuli presented in the L1. Furthermore, we found that fun movie clips presented in L1 (vs. L2) were associated with an enhanced response of the right amygdala, suggesting a stronger emotional resonance to positive stimuli. Crucially, activity in the right amygdala associated with the processing of L2 fun movie clips increased with increasing proficiency in the participants' L2, corroborating prior evidence on the modulatory role of proficiency on emotional processing differences across first and second languages.

4.3.1 Processing emotionally positive clips in a bilingual's two languages

Processing fun movie clips in both L1 and L2 led to overlapping activity in a bilateral temporal cluster including the middle and superior temporal cortices, in the inferior frontal cortex, and in the precuneus. We reconducted the selected fun movie clips to verbal humor processing, defining humor as any fun declaration or act which makes others laugh, including both the cognitive processes subserving the production and perception of that fun stimulus, and the emotional reactions to it (Martin, 2007). Humor is grounded in the ability to access to the second meaning of a joke without an explicit explanation (Ezrina & Valian, 2022). Thus, it crucially depends on both the retrieval of word meanings and the access to conceptual knowledge to grasp the less expected meaning. Indeed, humor processing has been shown to comprise a 'cognitive' component, related to language, semantic knowledge, Theory of Mind, and detection/resolution of message incongruity, and a more 'emotional' component associated with the feeling of amusement triggered by a humorous experience. The former, in particular, is thought to rely on a fronto-temporo-parietal network (e.g., Campbell et al., 2015; Vrticka, Black & Reiss, 2013) which we found to be activated for fun movie clips in both L1 and L2. Hence, our conjunction findings suggest that humor processing triggers access and retrieval of conceptual knowledge in both languages.

4.3.2 Processing emotionally negative clips in a bilingual's two languages

Interestingly, the conjunction analysis of sad movie clips revealed a completely different set of shared activations across the two languages, localized in the right middle occipital gyrus, the right superior occipital gyrus, and the right superior parietal lobe. As in the study of Goldberg et al. (2014), we found that sad movie clips in both languages activated preferentially the dorsal stream of the visual system, which has been associated with an action-related functional specialization (Chao & Martin, 2000). Whereas higher-order areas in occipito-temporal and parietal lobes have been systematically found to respond to emotional movie scenes (e.g., Eldar et al., 2007; Goldin et al., 2005), the right superior parietal lobule has been associated with a top-down evaluation of emotional stimuli (e.g., Barrett & Bar, 2009) as well as with emotion imitation mechanisms (e.g., Gallese, 2001; Leslie, Johnson-Frey & Grafton, 2004). Differently from fun movie clips, which may have triggered participants' reactions through very different cognitive

mechanisms, sad movie clips may have conveyed emotional contents not only (or not predominantly) through the verbal messages embedded in the scenes, but also through paralinguistic cues, such as facial expressions, proxemics, and bodily gestures. Paralinguistic information may have elicited intense emotional reactions in both languages, to the point of activating brain regions implicated not only in emotion recognition, but also in emotion simulation mechanisms (Bastiaansen, Thioux & Keysers, 2009; Gallese, 2001). Indeed, the cinematic power of sad films lies in their ability to make the viewer empathize with the character's state of mind.

4.3.3 Processing emotionally charged clips in L1 vs. L2

Enhanced activity in the left temporal cortex and the angular gyrus was observed for emotional stimuli presented in L1 (vs. L2). A greater activation of the anterior subdivision of the temporal lobe in L1 (vs. L2) has been reported during natural speech comprehension, such as listening to a story (e.g., Dehaene et al., 1997; Perani et al., 1996). The anterior temporal lobes (ATLs) are known to support conceptual knowledge, where the representations of word meanings, objects, people, and social concepts are stored (e.g., Rice, Lambon Ralph & Hoffman, 2015; Visser, Jefferies & Lambon Ralph, 2010). The angular gyrus has been conceptualized as a 'cross-modal hub' (Seghier, 2013) supporting the integration of multimodal semantic features (Binder & Desai, 2011; Kuhnke et al., 2023). A recent meta-analysis of fMRI studies on bilinguals' language processing highlighted a broader set of activated regions for lexico-semantic processing in L1 (vs. L2), among which left temporal structures and bilateral portions of the parietal cortex (Sulpizio et al., 2020b). It has been generally assumed that L2 words entertain weaker links to conceptual knowledge, resulting in a more effortful retrieval of meaning-related aspects, whereas L1 words would be characterized by stronger semantic associations to concepts, making their affective properties more easily and promptly activated (Kroll & Stewart, 1994). Thus, the greater activation of this temporoparietal semantic network for L1 vs. L2 emotional stimuli may reflect enhanced conceptual representations retrieval and integration in L1 in order to interpret upcoming multimodal (i.e., sensory and linguistic) inputs as instances of specific emotional events. Indeed, conceptual knowledge is made up of instances that have been acquired through social interactions or through personal experience in episodes. As, on the one hand, social interactions are mediated mainly by the L1, and, on the other hand, autobiographical

memories are thought to include a trace of the language of encoding (Marian & Neisser, 2000), an emotional instance encountered in the L1 would trigger greater language-dependent access to conceptual knowledge, resulting in a more defined emotional perception or experience.

4.3.4 Processing emotionally positive clips in L1 vs. L2

Interestingly, when inspecting separately the activations elicited by fun and sad movie clips, fun clips evoked greater activity in the right superior temporal cortex when presented in the L1 than L2. As previously stated, the superior temporal gyrus and the middle temporal gyrus are hubs within the semantic network, supporting the storage and retrieval of conceptual knowledge that underlies word meaning (Binder et al., 2009). In the conjunction analysis, we observed an enhanced activation of these regions, within a larger fronto-temporo-parietal network, for fun movie clips across the bilinguals' two languages (i.e., also when presented in their original English version). Nevertheless, their stronger activation for L1 (vs. L2) stimuli may underlie processing differences between languages, with a reduced reliance, in the L2, on semantic processes subserving the understanding the content-dependent aspects of verbal humor. Indeed, the processes of conceptual retrieval and integration which subserve humor appreciation may have been less efficient in the L2 context (see, e.g., Ayçiçeği-Dinn, Şişman-Bal & Caldwell-Harris, 2018; Ezrina & Valian, 2022), leading to a less intense emotional experience. This latter claim gains support from our findings on the modulatory role of L2 proficiency on the processing of fun movie clips presented in the L2.

4.3.5 The role of amygdala in L1 vs. L2 emotional processing

In the ROI analyses we observed a stronger response of the right amygdala for fun clips presented in L1 (vs. L2). The amygdala is a key subcortical region of emotional processing, as it is involved in triggering emotional resonance to stimuli (e.g., Guex et al., 2019; Janak & Tye, 2015). Furthermore, it has been consistently associated with the emotional component of humor processing, involved in humor appreciation (e.g., Bekinschtein et al., 2011; Campbell et al., 2015; Chan et al., 2012). Notably, a role of the amygdala in processing L1 vs. L2 emotional stimuli has been consistently reported in studies focusing on bilinguals' emotional processing (e.g., Hsu et al., 2015; Sulpizio et al., 2019; Liu et al., 2021). Indeed, it has been proposed that different lexicosemantic

activation thresholds arguably determine different emotional experiences (Liu et al., 2021), a claim that our results for L1 vs. L2 fun movie clips across the whole brain further supported. In the L1, less cognitive resources are required for language processing, allowing for a more in-depth processing of the emotional content (Dylman & Bjartå, 2019; Pavlenko, 2012; Ponari et al., 2015). Indeed, as previously mentioned, in the bilinguals' mental lexicon, the stronger associations characterizing L1 words lead to a faster and easier activation of semantic-related concepts, whereas the weaker associations of L2 determine a less automatic retrieval of meaning-related aspects. As such, we hypothesize that the greater recruitment of conceptual knowledge for L1 fun clips might have elicited stronger emotional responses contributing to the feeling of amusement associated with humorous experiences.

4.3.6 L2 proficiency effects on emotional processing in L2

More interestingly, the individual beta weights extracted from the right amygdala for L2 fun movie clips entertained a significant positive correlation with participants' L2 proficiency, meaning that the higher the level of attained L2 knowledge, the greater the amygdala reactivity to L2 fun movie clips. In other words, a higher proficiency in L2 seemed to be associated with stronger experiences of positive emotions elicited by fun movies presented in L2. This finding might suggest that, when the L2 is mastered at native-like levels, it is possible to pick up nuances or subtleties in the conveyed humoristic verbal message that enriches its meaning. Indeed, higher levels of language proficiency may facilitate lexical retrieval (de Bruin, Della Sala & Bak, 2016; Micheal & Gollan, 2005). As proficiency increases, the bilinguals' mental lexicon becomes more integrated across the two languages, to the point that a word presented in one language automatically triggers the mental representation of its translation in the other language (Kroll & Tokowicz, 2005). High proficiency in L2 could thus strengthen associations between L2 words and corresponding semantic concepts (Kroll & Stewart, 1994), leading to easier accessibility of their affective connotations. This, in turn, may determine a stronger emotional reaction of amusement to the positively valenced stimuli presented in L2.

4.3.7 Conclusions

We investigated neural correlates of bilinguals' emotional processing by means of a naturalistic viewing paradigm, which allowed us to mirror more closely what happens

in real life when bilinguals face emotional events. To the best of our knowledge, this is the first study to examine in an ecological manner bilinguals' perception and experience of emotional stimuli. The pattern of findings reported in this study extends previous evidence of general differences in emotion processing between L1 and L2, and corroborates the hypothesis that language provides a context for the construction of emotions. Furthermore, our findings extend the constructionist view to second language processing, highlighting that emotion reactions might be weaker in languages with a poorer conceptual knowledge that does not allow to reach a native-like level of abstraction from instances with heterogeneous features. Nevertheless, the underlying differences in how closely emotion concepts are associated with affective language in L1 vs. L2 can be reduced by increased proficiency in the L2. Thus, watching movies in the first language allows us to emotionally resonate to their content, yet watching them in a second language may reinforce links between L2 words and corresponding semantic concepts, ultimately leading to a (almost) native-like emotional experience.

4.3.8 Limitations of the study

It is worth mentioning a few limitations of Experiment 3. First, although accuracy rates were almost at ceiling for all emotion categories in both languages, we cannot completely rule out the possibility that participants may not have attained a native-like understanding of movies presented in English. Second, we acknowledge that we cannot affirm with certainty that the increased activation of the right amygdala represents an actual increased emotional experience to fun stimuli in L1, as we did not collect from our participants emotional ratings for the presented movie clips after the MRI scanning. Moreover, we acknowledge that Italian movie clips, being dubbed from the original English versions, may suffer from a subtle lack of synchronization between people's mouth movements and their speech, which in turn may have introduced some noise into the observed brain activity. Indeed, in natural conversations, speech comprehension is thought to be aided by congruent visual mouth and lip movements (e.g., Begau et al., 2021; van Wassenhove et al., 2005). In addition, incongruent audiovisual stimuli have been shown to produce novel percepts that do not match either auditory or visual information (McGurk & MacDonald, 1976). Audio and visual stimuli are thought to be integrated into a single percept in the superior temporal sulcus, a multisensory integration area (Miller & D'Esposito, 2005; Werner & Noppeney, 2010). Moreover, incongruent

audiovisual stimuli have been shown to recruit the inferior frontal gyrus, presumably reflecting enhanced cognitive demands (Hein et al., 2007; Jones & Callan, 2003). Therefore, as the visual and audio information was not perfectly matched, processing dubbed Italian film clips may have required additional cognitive resources to integrate the slightly mismatched sensory inputs into a single percept. However, it should be note that first-language speakers of Italian are very familiar with dubbed movies, thus making the handling of subtle audiovisual mismatches a real-life experience.

4.4 EXPERIMENT 4 (DISCUSSION)

Experiments 2 and 3 reported differences in the neural correlates of emotional processing between a bilinguals' two languages, with stimuli presented in the L1 evoking enhanced responses in brain regions involved in emotional processing. As emotions are thought to influence cognition and behavior, differences in emotional reactions might lead to corresponding differences in thoughts, actions and decisions. Bilinguals are indeed called upon to make many decisions every day, not always in their first language. Therefore, determining the potential impact of language on people's decisions is an ongoing fruitful research field. Furthermore, it is yet to be determined which dimensions of bilinguals' language experience contribute to the FLE. To fill this gap, Experiment 4 assessed the effect of language context on moral decision-making, then evaluating the modulatory role of bilingual language experience on participants' responses to moral dilemmas presented in the L2. Our results showed dilemma-specific FLEs that seemed to be determined by features related to normative knowledge more than emotionality. Moreover, bilingual dimensions were found to interactively shape bilinguals' moral decisions and judgments, as well as their emotional reactions, in a more complex way than previously theorized.

4.4.1 Assessing the effect of language context

Language context exhibited a significant effect on participants' probability to harm one person for a greater good in the *Bike week* dilemma, but neither in the *Surgeon* nor in the *Factory* dilemma. This finding was somewhat surprising given that all scenarios were kept as homogeneous as possible in terms of design parameters, information

structure, expression style, and wording, both within and between languages. Thus, the fact that the FLE was restricted to the *Bike week* dilemma may suggest that each dilemma is endowed with unique content features triggering a less deontological and/or more utilitarian responding. It might be the case that these features have peculiar emotional connotations that would make a scenario to be perceived as more arousing than others. As such, that scenario would be subjected to a greater extent to the dampened emotionality of a L2, displaying the FLE. Nevertheless, contrary to this hypothesis, we failed to observe a significant effect of language context on participants' perceived emotional distress in all dilemmas. Therefore, our findings seem to contradict also the reduced emotionality hypothesis which ascribes the FLE to a blunted emotional resonance in L2 (for similar findings, see, for instance, Chan et al., 2016; Geipel et al., 2015a, b; Miozzo et al., 2020; Muda et al., 2020). On the other hand, the FLE observed in the *Bike week* dilemma was accompanied by a significant effect of language context on participants' perceived permissibility of the depicted moral violation, showing that pushing the biker off the road to save five people was perceived as more acceptable in the L2 (vs. L1). The results we obtained for both moral decisions and norm judgments in *Bike week* thus seem to support the reduced access to norms hypothesis, according to which morality in a L2 would be turned down due to a less automatic access to normative knowledge (e.g., Gawinkowska, Paradowski & Bilewicz, 2013; Geipel et al., 2015a, b). Accordingly, it might be the case that each scenario would be differently subjected to language effects triggering context-specific features that tap onto normative principles rather than emotionality. A significant effect of language context on norm judgments was detected also in *Surgeon*, with higher permissibility ratings given by participants assigned to the L2 context (versus those in the L1 context), although there were no differences in moral decisions between the two language contexts. The dissociation observed in *Surgeon* may thus reveal different mechanisms underlying first-person decisions (triggered by questions such as 'Do you decide to perform the described action?') and norm judgments (triggered by questions such as 'How do you rate the described action on a scale from forbidden to obligatory?'). Indeed, first-person decisions and norm judgments have been shown to elicit a different processing (Garrigan, Adlam & Langdon, 2016) and to lead to different results (Tassy et al., 2013). Our results thus extend this dissociation between

moral decisions and norm judgments to L2 settings, suggesting that the way in which moral questions are framed might determine the emergence of the FLE.

4.4.2 Assessing the effects of bilingual language profile

An interactive effect of L2 AoA, L2 proficiency, and language dominance on the probability of utilitarian responding was detected in the *Surgeon* dilemma, in spite of any significant effect of bilingual language background both in *Bike week* and in *Factory*. When the three-way interaction was inspected separately for early and late bilinguals, two opposite patterns of moral behavior emerged. Indeed, in early bilinguals utilitarian tendencies increased with increasing proficiency in L2 when the L1 was dominant, and decreased with decreasing L2 proficiency when the two languages were (almost) equally dominant. On the other hand, in late bilinguals utilitarian inclinations decreased with increasing L2 proficiency when the L1 was dominant, whereas they remained constantly low when the two languages were (almost) equally dominant. Our findings thus reveal an intricate scenario, at least in part inconsistent with the prediction of a reduced alignment with utilitarianism in L2 contexts with increasing levels of L2 proficiency and exposure supported by both the reduced emotion hypothesis and the hypothesis. Nevertheless, such explanatory hypotheses have been mostly developed from data obtained on L2 learners, that is unbalanced speakers who raised in environments in which the L1 was dominant and learnt their L2 in instructional settings. Among such group, low proficient bilinguals, as compared to those with a high proficiency, have been typically found to display an enhanced utilitarian inclination when using the L2 (e.g., Corey et al., 2017; Costa et al., 2014; Geipel et al., 2015b; but see Mills & Nicoladis, 2020). Although partially consistent, the results we obtained in late bilinguals extend this previous evidence, highlighting the role of language dominance in driving moral decision-making in a late acquired L2. More broadly, our findings suggest that the interindividual variability in the interplay between proficiency and dominance would differentially shape bilinguals' moral decisions in a L2 as a function of their AoA. Indeed, recent neuroimaging evidence highlighted the interactive role of proficiency, usage or dominance, and AoA in modelling both the functional and structural organization of the bilingual brain (e.g., Fedeli et al., 2021; Gullifer et al., 2018; Sulpizio et al., 2020a). Accordingly, we showed that variability along these interrelated dimensions also modulate decision-making processes in a L2,

strengthening the notion of bilingualism as a continuous and multidimensional phenomenon.

Furthermore, significant effects of bilingual language profile were detected also on norm judgments for both *Surgeon* and *Bike week*. A significant interaction between L2 AoA and L2 proficiency on norm judgment emerged in *Surgeon,* revealing that, with increasing proficiency, the moral violation was perceived as more acceptable in early bilinguals, and less permissible in late bilinguals. The results observed for late bilinguals are consistent with the cognitive enhancement hypothesis of increased deontological concerns in the L2 when the proficiency in L2 is high, whereas early bilinguals displayed an opposite tendency. Remarkably, these patterns are consistent with the findings observed for moral decisions in the same dilemma. In the *Bike week* dilemma, L2 AoA and Language Dominance were shown to significantly interact in modulating participants' norm judgments, with higher permissibility ratings associated with a higher balance in language dominance between the two languages in both early and late bilinguals. This finding is particularly difficult to explain within any of the previous accounts of the FLE.

Moreover, bilingual language profile was found to influence also bilinguals' perceived emotional distress for both *Factory* and *Bike week.* In the *Factory* dilemma*,* distress ratings were higher with increasing L2 proficiency, in line with the hypothesis that high proficiency promotes emotional grounding (Costa et al., 2014). In both *Factory* and *Bike week,* L2 AoA and language dominance were found to significantly interact, showing an increased emotional distress when the L2 dominance increased, but only in late bilinguals.

Overall, our results highlighted that the interplay of the bilingual dimensions explored (i.e., AoA, proficiency, and language dominance) has the potential to shape bilinguals' decision-making in a second language. Crucially, our findings suggest the need to reconceptualize previous explanations of the FLE and their implications on bilinguals' moral decision and judgment.

4.4.3 Conclusions

In the present study, a stimulus-specific FLE was observed for dilemmas different from the classic Trolley/Bystander/Footbridge moral scenarios. Moreover, we found evidence supporting the conceptual distinction between moral decisions and norm judgments, suggesting that the framing of moral questions may lead (or not) to the emergence of the FLE. In addition, a continuous approach to bilingualism allowed us to detect more nuanced and insightful effects of bilingual language profile on moral decision-making. As such effects were not fully aligned with previous accounts, especially for what concerns early bilinguals, we stressed the need to reconceptualize the FLE and its implications on moral decision-making.

4.4.4 Limitations of the study

A few limitations of Experiment 4 should be acknowledged. First, we did not assess our participants' decision-making style and personality traits, which may exert an effect on the explored variables. Second, we did not collect bilingual language profile measures from participants assigned to the L1 condition. Third, experimental stimuli were sacrificial scenarios, which however have been criticized for low likelihood of occurrence (e.g., Bauman et al., 2014). Thus, future research should adopt dilemmas that more closely mirror the moral situations people can face in real-life.

4.5 EXPERIMENT 5 (DISCUSSION)

Although the current literature on the nature of the FLE is rapidly increasing, bilinguals' decision-making in a L2 under uncertain conditions, where information about the probability of occurrence of alternatives and their outcomes are unknown, has been so far unexplored. Yet, real-life decisions are characterized by uncertainty rather than certainty. Accordingly, in Experiment 5 we inspected whether using a L2 (versus a L1) and/or presenting uncertain scenarios (versus certain) would affect participants' decisions in both moral dilemmas and exploration-exploitation problems. We found evidence for a limited FLE on decision-making in both moral dilemmas and exploration-exploitation problems. Then, adopting the same continuous approach of Experiment 4, we assessed

whether the bilingual dimensions of proficiency, immersion, and exposure modulated participants' responses in a L2, observing specific bilingualism-related effects on participants' responses. Finally, we evaluated whether such effects were further modulated by participants' individual traits, i.e. cognitive style and risk-taking attitude, showing that these measures significantly interact with bilingual dimensions in shaping bilinguals' decision-making.

4.5.1 Assessing the effects of language context and problem condition

In the between-group analyses, we observed mixed (mainly null) effects of language context (L1 vs. L2) and problem condition (certain vs. uncertain) on participants' responses. Specifically, both predictors failed to significantly affect participants' choices in both moral dilemmas and exploration-exploitation problems. On the contrary, in spite of null effects of problem condition, the effect of language context on norm judgments reached significance in the *Bike week* dilemma, where the use of a L2 was associated with a higher perceived permissibility of the depicted moral violation (i.e., pushing the biker off the road).

Currently, the state of art on the FLE is characterized by mixed evidence, with some studies reporting stronger utilitarian versus deontological tendencies when making decisions and judgments in a L2, and some others failing to consistently replicate such pattern (e.g., Białek et al., 2019; Feng, Liu & Nolasco, 2023; Hayakawa et al., 2017; Muda et al., 2020b; Nadarevic, Klein & Diederolf, 2021). Indeed, consistently with Experiment 4, our results evidenced a limited (i.e., stimulus-specific and question-specific) language effect on participants' moral decision-making. In particular, the use of a L2 failed to significantly affect participants' moral choices, yet it reduced participants' concerns on the deontological admissibility of moral violations in *Bike week* (i.e., permissibility ratings). As already outlined for findings of Experiment 4 (see section 4.4.1), the fact that the FLE was not detected in both moral dilemmas further strengthens the hypothesis that each scenario is endowed with peculiar content features that would trigger more utilitarian or less deontological tendencies, thus determining the emergency of a FLE (e.g., Chan et al., 2016). Furthermore, the fact that the FLE failed to occur in both moral decisions and norm judgments supports the claim already discussed in

Experiment 4 (see section 4.4.1) that the FLE would depend on the framing of moral questions (i.e., first-person choices versus evaluations of moral violations).

Remarkably, the null effects of problem condition on both participants' moral choices and norm judgments indicate that, contrary to our predictions, information related to future events (whether it is given for sure or not) seems neither to influence itself nor to interact with language context in driving morality.

Exploration-exploitation problems involve a trade-off between repeating a past action in expectation of an already known outcome (exploitation), and engaging in a novel action whose outcome is uncertain but potentially of superior value (exploration). Thus, we hypothesized participants assigned to the L2 context to show a greater tendency toward the riskier, exploratory alternative than those in the L1 context. Indeed, the use of a L2 has been suggested to reduce risk aversion, leading to perceive potential risks endowed in many activities and technologies (e.g., traveling by plane) as less risky and more beneficial (Hadjichristidis et al., 2015). Nevertheless, although using a L2 versus the L1 led to a marginally higher proportion of explorative (vs. conservative) choices in both problems, such differences were not statistically significant.

According to the reduced emotionality hypothesis (see section 1.5.2, for a broader discussion), the FLE would arise from "colder" emotional reactions to moral infractions elicited by decision-problems presented in a L2. Indeed, processing a L2 ends up in a weakened emotional involvement, especially in unbalanced bilinguals (for a review, see Pavlenko, 2017). Thus, facing a moral decision in a L2 would prevent emotions sparking gut-feeling reactions (i.e., activate System 1) that might distort judgments and choices (Greene et al., 2004), leading people to align to a lesser extent with ethical norms. Contrary to this account, language effects on participants' choices, when detected, were not accompanied by an attenuation of negative emotions, as in Experiment 4. Additionally, the significantly larger proportion of utilitarian vs. deontological decisions associated with using a L2 in the *Bike week* dilemma was associated with higher emotional distress ratings in the L2 than in L1. Notably, this finding was relatively constant across dilemmas and problems, and irrespective of whether information about potential outcomes was given for sure (i.e., certain) or not (i.e., uncertain). The fact that we did not observe an association between the FLE and emotional processing, as in

Experiment 4 and in many other studies on the topic (e.g., Chan et al., 2016; Geipel et al., 2015a,b; Miozzo et al., 2020; Muda et al., 2020b), stresses the need to redefine, at least in part, the mechanisms underlying the FLE.

4.5.2 Assessing the effects of bilingual language profile

In line with Experiment 4 (and Experiment 3, as well), we adopted a continuous and multidimensional approach to bilingualism, considering the extent to which individuals vary as bilinguals along several interrelated dimensions. Here we focused on L2 proficiency, L2 exposure, and L2 immersion. These variables were found to interactively modulate participants' choices in both moral dilemmas and exploration-exploitation problems. Nevertheless, consistently with Experiment 4, the modulatory role of specific dimensions of bilingual language profile was not ubiquitous across all problems, independently of the language effects we detected in the between-group analyses. These findings thus strengthen the claim we advanced in Experiment 4 that interindividual variability in bilingual experience has the potential to shape bilinguals' decisions in a L2, without this necessarily leading to the "classic" FLE on decision-making (see section 4.4.2). Furthermore, in line with the results of Experiment 4, the direction of the significant effects of bilingual dimensions on participants' choices and emotional distress was not always consistent across problems and scenarios, and in some cases inconsistent with previous accounts. For instance, in the uncertain version of the *Surgeon* dilemma, in spite of a null effect of language context on participants' decisions, we found a significant effect of L2 exposure on both moral decisions and norm judgments. In particular, results showed that, with increasing exposure to the L2, on the one hand, the moral violation was perceived al less permissible, in line with previous theorizing, and, on the other hand, the utilitarian tendencies increased, contrary to the claim that a more symmetrical use of the two languages (i.e., a higher exposure to the L2) would enhance bilinguals' deontological inclinations. In addition, we found an increased probability of exploratory choices for higher levels of L2 proficiency in both exploration–exploitation problems, disconfirming our prediction.

4.5.3 Assessing the effects of cognitive style and risk tendencies

Bilingualism-related effects were found to interact with cognitive style (CRT scores) and risk-taking attitudes (PID-5 scores) in modulating participants' decision-making in

both moral dilemmas and exploration-exploitation problems. Notably, cognitive reflection contributed to a greater extent in driving utilitarian (versus deontological) decisions, whereas risk-taking attitude in shaping exploration (versus exploitation) choices. For instance, in the uncertain version of *Surgeon*, with increasing L2 exposure, the probability of choosing the utilitarian option increased when the propensity toward reflective reasoning was high, whilst it decreased when the propensity toward reflective reasoning was low. In *Broken glass*, with increasing L2 immersion, participants' explorative behavior increased when risk-taking attitude was high, and decreased when risk-taking attitude was low. Overall, these results are consistent with previous evidence on monolinguals showing that propensity toward reflective thinking can predict utilitarian tendencies (e.g., Paxton, Ungar & Greene, 2012), on the one hand, and risk-attitude can drive decisions toward exploration (e.g., Wittmann et al., 2008), on the other hand. Moreover, our results highlight that such relatively stable aspects of reasoning and personality would interact with more dynamic variables related to bilingual experience in shaping people's decision-making, possibly leading to effects apparently in contrast with previous theorizing (as in both Experiment 4 and in previous analyses).

4.5.4 Conclusions

In the present study, the pattern of results did not allow us to draw any conclusions about the occurrence, characteristics and origin of the FLE on decision-making. Also, the uncertainty of alternatives and outcomes was found to have uncertain effects on bilinguals' decisions and judgments. Moreover, we detected significant effects of measures related to bilingual language experience on bilinguals' decisions. Importantly, such effects were found to interact with measures related to cognitive style and risk-taking attitude in shaping bilinguals' choices. Accordingly, the FLE should be reconceptualized considering also the modulatory role of both bilingual dimensions and individual traits.

4.5.5 Limitations of the study

The present study is affected by some limitations. As in Experiment 4, moral scenarios might lack ecological validity as they do not closely represent situations people can face in real life. Nevertheless: (1) we explored decision-making processes in uncertain contexts in order to provide a more ecological picture of bilinguals' choice behavior; (2) the use of simple, artificial scenarios allowed us to experimentally control both

conceptual and methodological factors that might bias people's judgment (Christensen & Gomila, 2012).

4.6 GENERAL DISCUSSION

The present dissertation assesses the nature of the relationship between language and emotion in both monolingual and bilingual speakers. Language and emotion have long been considered separate entities, each characterized by their own representations and processes. Consequently, their association has been conceived as unidirectional, with language allowing us to communicate the emotions we are feeling. However, the view that this relationship is bidirectional is gaining ground. Indeed, language is involved in the perception and experience of a variety of sensory inputs, supporting the buildup and arrangement of concepts that guide the interpretation of stimuli in terms of the stored categories. Accordingly, language is thought to provide the context for the construction of emotion fostering the development and organization of emotion conceptual knowledge, which is accessed to make meaning of an upcoming valenced instance in terms of a specific emotion category. As abstract concepts, such as emotion ones, are stored in conceptual knowledge as collections of heterogeneous modality-specific instances, they can vary considerably in both content and application. Hence, conceptual knowledge shows considerable intra- and interindividual variability. Notably, it varies across languages that encode different emotion concepts, with corresponding changes in emotion perception and experience. In today's increasingly bilingual world, it is necessary to determine the presence and possibly the extent of such differences in a bilingual's emotional life. Indeed, our emotional response to a stimulus determines our subsequent behavior toward it, our actions, our thoughts, our decisions. The five experiments in the present dissertation are a linear exploration of these aspects, starting from the assessment of the relationship between language and emotion in monolinguals (Experiment 1), then extending the investigation to bilinguals (Experiments 2 and 3), and finally evaluating its implications on bilinguals' decision-making (Experiments 4 and 5).

A tight relationship between linguistic and emotional competence has been widely reported in developmental literature, with superior language skills leading to better emotional abilities and, hence, to improved personal, school-work and social functioning

(Conte et al., 2019; Pan, Li, & Lin, 2022; Westrupp et al., 2020). Crucially, language achievement has been typically quantified in terms of vocabulary knowledge, referring to all aspects involved in word knowledge (Milton & Fitzpatrick, 2013; Nation, 2019; Schmitt, 2014). A broadly used dimension of vocabulary knowledge is vocabulary size, that is the total number of known words. Broader general (e.g., Beck et al., 2012; Grazzani et al., 2018; Griffiths et al., 2020) and emotion-specific (e.g., Grazzani & Ornaghi, 2011; Li & Yu, 2015; Streubel et al., 2020) vocabularies have been systematically found to correspond to greater emotional competencies, suggesting that language, and emotion language in particular, drives children's socioemotional development (Bell et al., 2024). Therefore, this evidence has been taken to support the constructivist claim that words boost the acquisition of and access to emotion conceptual knowledge, defining the categorization of different sensations, actions, and situations in terms of discrete emotions (e.g., Cole, Armstrong & Pemberton, 2010; Doyle & Lindquist, 2018; Lupyan, 2012). Indeed, the acquisition of emotion concepts seems to proceed in tandem with language development. As linguistic abilities develop, children begin to acquire emotion concepts that are used to interpret perceived valenced sensations as instances of discrete emotions (Wu et al., 2023), shifting from a narrow positive vs. negative categorization to a broader fine-grained emotion conceptual knowledge (Shablack & Lindquist, 2019). Throughout adolescence, while linguistic skills are strengthening, emotion conceptual knowledge keeps expanding and adjusting (Nook et al., 2017, 2020; O' Kearney & Dadds, 2004). By adulthood, linguistic skills have matured; yet new experiences may allow novel words to be acquired and, hence, conceptual knowledge to expand (Doyle & Lindquist, 2018; Fugate et al., 2010). Nevertheless, how vocabulary knowledge contributes to emotional perception and experience in adulthood remains largely unexplored. Thus, to the best of our knowledge, Experiment 1 is the first attempt to assess whether individual differences in breadth of both general and emotion vocabulary knowledge were associated with distinct profiles of emotion perception from morphed faces in young adults. Participants' performance in both the categorization and the discrimination tasks revealed a categorical perception of morphed emotional faces, in line with previous evidence (e.g., Fugate, Gouzoules & Barrett, 2010; Jacques & Caharel, 2022; McCullough & Emmorey, 2009). Our findings are also in line with a growing body of studies on the effects of language on perception of a variety of sensory inputs, such as colors (e.g., Peirolo et al., 2023;

Sinkeviciute et al., 2024; Thierry et al., 2009), motion (Bidet-Ildei, Sparrow & Coello, 2011; Flecken et al., 2015; Vanek & Fu, 2022), speech (Bidelman & Lee, 2015; Lyu et al., 2024), and objects (Navarrete, Miozzo & Peressotti, 2020; Noorman, Neville & Simanova, 2018). A consistent finding is that language induces categorical perception of such stimuli (Lupyan et al., 2020). In particular, instances are more likely to be clustered within the same category if they are labelled similarly (Gervits, Johanson & Papafragou, 2023), showing that linguistic labels trigger category formation (Johanson & Papafragou, 2016). Accordingly, using emotion conceptual knowledge to interpret facial configurations would lead emotions to be categorically perceived (Fugate, 2013). Thus, emotion conceptual knowledge has the potential to shape the ongoing construction of an emotion. As such, even slight interindividual differences in the organization of emotion conceptual knowledge may lead people to differently group emotions into categories (Brooks & Freeman, 2018). Notably, results of the correlation analyses we performed go in this direction. On the one hand, participants with broader emotion vocabularies showed a more abrupt shift in perception from the "fear" to the "happiness" category when categorizing morphed faces. On the other hand, participants with wider receptive general vocabularies exhibited a greater between-category advantage. Hence, a broader vocabulary knowledge, both domain-general and emotion-specific, seems to lead to a sharper sorting of perceptually ambiguous stimuli into categories. A greater availability of concepts would allow for a more defined emotional experience from an ambiguous facial configuration, suggesting that structural information alone is not sufficient for categorical perception. As mentioned in section 4.1.5, our conclusions are drawn from correlational data, so they do not allow us to determine the direction of the relationship between vocabulary size and emotion perception. Future research is thus required to formally establish the direction of such association.

As language guides perception, languages labelling concepts with different words would vary also with respect to the interpretation of incoming inputs. For instance, Thierry and colleagues (2009) found that the existence of two Greek terms to distinguish between light and dark blue led to a better and faster perceptual discrimination of these colors in first-language speakers of Greek vs. first-language speakers of English, further showing that first-language terminology unconsciously affected early stages of color perception. Accordingly, it is increasingly recognized that speaking different languages

affect also the perception and experience of emotions (e.g., Crivelli et al., 2016; Gendron et al., 2014; Jack et al., 2016). As bilingualism is an increasingly common phenomenon, research on the effects of speaking more languages on emotion has been steadily on the rise. Whereas bilinguals generally report their first language as more authentic and emotional than their later acquired one(s) (e.g., Dewaele, 2010; Marcos, 1976; Pavlenko, 2012), evidence for bilinguals' emotionality is inconsistent across studies using objective measures. Therefore, it has yet to be determined whether and to what extent emotional stimuli and situations are experienced in a first vs. a second language. Experiments 2 and 3 build on this state of the art, motivated by the desire to elucidate the neural mechanisms that regulate emotional processing in a bilingual's two (or more) languages. Specifically, in Experiment 2, an EST was used to assess the automatic processing of emotionally charged stimuli. A sample of middle-to-high proficient Italian-English bilinguals, who acquired their L2 mostly in formal or mixed settings, performed the task while their functional brain activity was registered in the MR scanner. We failed to detect significant differences between the first and the second language in the automatic processing of emotional words, in line with previous studies (e.g., Ahn & Jiang, 2023; Eilola, Havelka & Sharma, 2007; Grabovac & Pléh, 2014). On the contrary, we observed enhanced brain activity for L1 vs. L2 emotional words in portions of the posteromedial cortex associated with attention, memory retrieval, and affective processing. These fMRI findings could not be interpreted on the basis of behavioral effects, as they showed no differential automatic processing of emotional words across both languages. The discrepancy between behavioral and brain responses may be attributed to a different sensitivity to the emotional charge of words in L1 and L2. Additionally, this divergence may also highlight that the EST does not adequately capture potential emotionality effects on word processing across languages. The EST has been widely used with clinical populations administering emotional words related to a specific pathology or dysfunctional personality trait (e.g., anxiety, depression, phobia; Williams et al., 1996). Yet its use to explore implicit processing of emotional words in healthy subjects, irrespective of how many languages they spoke, led to inconsistent findings, often in contrast with psychophysiological and brain imaging data (see, for reviews, Phaf and Kan, 2007; Jończyk, 2016). Remarkably, we did not observe the classic emotional Stroop effect in either participants' L1 or L2 at the behavioral level. As such, Experiment 2 further

supports the claim that the EST, at least in the version we adopted, is not adequate to detect effects that can be snatched by neuroimaging techniques. Therefore, other tasks evaluating emotional interference, or other variants of the EST tapping on a more intense emotional conflict (Song et al., 2017) should be adopted in future studies. Experiment 2 thus suggests a complex role of a bilingual's languages in their emotional lives, which might be influenced by many factors. On the one hand, as bilingualism is a continuous phenomenon, along which people vary as bilinguals according to several interrelated dimensions, it is likely that a composite interrelationship between such dimensions determines how bilinguals react to emotional stimuli in their languages. On the other hand, the use of single words as experimental stimuli does not allow to investigate real-life bilinguals' emotional processing. To overcome the limitations of Experiment 2, in Experiment 3 we assessed bilinguals' emotional processing through a naturalistic viewing paradigm, such as watching emotionally charged movie clips, further exploring the moderating effects of bilingual dimensions on emotions. To the best of our knowledge, Experiment 3 represents the first investigation of the neural underpinnings of processing emotional naturalistic stimuli in bilingual speakers. Recently, Dewaele and colleagues (2021) assessed emotional reactivity to watching television in English in both first-language speakers of English and in first-language speakers of Greek and Hungarian for whom English was the L2. They found a higher self-reported emotional reactivity to the television contents watched in English in first-language speakers as compared to second-language speakers of English. Our findings thus expand such evidence, suggesting that watching emotionally charged movies in the mother tongue vs. a foreign language recruits to a greater extent semantic-related brain regions (Binder et al., 2009; Rice, Lambon Ralph & Hoffman, 2015). In line with a constructionist perspective of emotion, we interpreted our results as showing prompter and deeper access to conceptual knowledge when making meaning of dynamic multisensory information presented in a bilingual's first language. As language participates in constructing emotions, a greater retrieval of conceptual knowledge would be triggered by any emotional instances presented in the first language. Additionally, our results revealed for funny movies presented in the L1 vs. L2 an enhanced response in a temporal region involved in semantic processes associated with verbal humor comprehension (Campbell et al., 2015; Vrticka, Black, & Reiss, 2013). Accordingly, we hypothesized that the first language carries out a more efficient

conceptual retrieval during humor processing, ultimately leading to deeper emotional resonance. In support of this claim, our ROI analyses showed a stronger response of the right amygdala to funny movies in the L1 (vs. L2), further supporting our proposal that greater language-dependent conceptual access triggered more intense feelings of amusement associated with humorous content. Nevertheless, we observed a moderating role of L2 proficiency on the response of the right amygdala to funny movies presented in English, with higher levels of L2 competence associated with stronger amygdala responses. Thus, an increased proficiency in the second language would allow to capture nuances in humoristic contents that enrich their meaning, ultimately leading to a more intense emotional experience of amusement when watching movies in a L2. Experiment 3 thus shows that differences in emotionality between a bilingual's two languages may indeed exist, but that traditional research paradigms, in which simple stimuli are used, may not be powerful enough to capture them. On the contrary, naturalistic stimuli, due to their dynamicity and multidimensionality, allow us to assess what happens in real life when bilinguals face emotionally charged situations. Moreover, through Experiment 3 we stressed the need for considering bilingual dimensions when evaluating how bilinguals react to emotional stimuli presented in their first and second languages. Indeed, bilingualism-related aspects have been shown to lead to several structural and functional changes within a bilingual brain (e.g., Del Maschio et al., 2019; Singh et al., 2018; Sulpizio et al., 2020a). Furthermore, an influence of such aspects on bilinguals' emotional processing has been reported (Pavlenko, 2017). Accordingly, future research ought better to take into account also interindividual differences in bilingual language experience when trying to determine bilinguals' emotional resonance.

As our emotional reactions are determinant for our thoughts and subsequent actions, experiencing emotional instances differently based on the language in which we encounter them would trigger different outcomes. Our decisions and judgments should be affected, too. Experiments 4 and 5 build on this assumption by investigating whether bilinguals' morality is affected by the language in use. In particular, language effects on moral choices (deontological vs. utilitarian tendencies), norm judgments (the perceived permissibility of a moral violation), and emotional distress (the extent to which each moral dilemma triggered feelings of worry, upset, and sadness) were evaluated. Additionally, in both studies the modulatory effects of bilingual dimensions on moral

decision-making, norm judgment and emotionality in a second language were assessed. Therefore, in both experiments we adopted a complementary analytic approach: (1) a between-group analysis was run to assess the effects of language context (L1 vs. L2) on participants' responses, (2) a within-group analysis evaluated the modulatory effects of bilingual language experience on participants' moral decisions and judgments in a L2. In both experiments, between-group analyses suggest that the emergence of the FLE is heavily dependent on the dilemma at hand, with less deontological or more utilitarian tendencies eventually prompted by its unique features. Surprisingly, an increased willingness to commit harm in order to achieve greater good was qualified by a higher perceived permissibility of the prospected moral violation. Accordingly, an increased alignment with utilitarianism (or a reduced reliance on deontology) in a L2 seems to be driven not by a dampened emotionality, leading to a more rational decision-making, but by a less automatic access to normative knowledge. Our findings thus contribute to current literature of the FLE providing evidence in support of the reduced access to norm hypothesis (Geipel et al., 2015a, b). On the contrary, the reduced emotionality hypothesis (Costa et al., 2014) was not supported by our results, as participants' distress ratings were either comparable between the two languages or even higher in the L2. Importantly, such evidence was reported in other studies (e.g., Geipel et al., 2015; Miozzo et al., 2020; Muda et al., 2020), highlighting the need to redefine current explanatory hypotheses of the FLE. Moreover, our results show that these concluding remarks also hold for uncertain scenarios. Indeed, with Experiment 5, we extended the investigation of FLE to uncertain decision contexts where the decision maker is unaware of the probability of occurrence of each alternative and their consequences. Our goal was to more closely reflect real-life decision situations where we typically do not know the outcome of a particular choice with certainty. Crucially, we found that uncertainty did not influence the emergence of FLE, further suggesting that this phenomenon is highly dependent on the depicted scenario (e.g., Chan et al., 2016). Additionally, in both Experiments 4 and 5, we observed nuanced effects of participants' bilingual language background on their moral choices, norm judgments, and emotional reactions. L2 AoA, L2 proficiency and language dominance, in Experiment 4, and L2 proficiency, L2 immersion and L2 exposure, in Experiment 5, were found to interactively exert significant influences on bilinguals' decision-making in a second language. Nevertheless, in both studies the observed effects

of bilingual dimensions on participants' responses were not always consistent across problems and scenarios, and also with previous explanations. Crucially, such effects were independent from the influence of language context, leading us to conclude that: 1) bilingual dimensions might affect decisions, judgments and emotions, without necessarily leading to a FLE; 2) a FLE might be determined by other factors than language background. Accordingly, in Experiment 5 we tested whether individual differences in cognitive style and risk-taking attitude interacted with bilingualism-related effects in determining participants' responses. Indeed, an enhanced likelihood to align with the utilitarian option has been associated with increased reflective thinking (e.g., Pennycook et al., 2018) and greater risk-taking attitudes (e.g., Vinson et al., 2020) in monolingual speakers. Interestingly, our findings show that such reasoning and personality traits might modulate the effects of bilingual dimensions leading to findings that apparently contradict previous evidence. Therefore, future studies should consider interindividual variability in both bilingual experience and cognitive and personality measures when trying to assess the effect of the language of presentation on bilinguals' decisions. As our experiments reported (Experiments 3, 4 and 5), speaking and being exposed to more languages can exert subtle and nuanced effects on our perceptions, cognitions, emotions and actions, making it difficult, if not impossible, to reduce these effects to a simple effect of the first vs. a second language.

4.6.1 Concluding remarks

Bilingual people generally find that their positive and negative feelings are expressed more powerfully and authentically in their first language. But why would the expression "I love you" carry the most emotional weight when said in one's first language (e.g., Dewaele, 2008)? Or why should we find a movie funnier when seen in the first language (e.g., Bellini et al., 2024; Dewaele et al., 2021)? The current dissertation attempts to answer such questions assessing the role of language in emotion in both monolingual and bilingual speakers. In line with contemporary constructionist accounts of emotion (e.g., Barrett, 2006a; Lindquist, 2013), our findings revealed that previously developed categories, supported by language, shape the perception and experience of emotions. As both the structure and the content of conceptual knowledge is thought to be idiosyncratic, being anchored in individual experiences, emotions would vary with respect to their perceptual and experiential connotations across individuals. We also showed a linguistic

relativity of emotion conceptual knowledge, which in turns lead to corresponding differences in the emotional reaction to arousing stimuli between a bilingual's two languages. However, these effects may not be identified through the use of isolated stimuli, such as single words (e.g., the EST), at least at a behavioral level. Instead, more ecological emotional stimuli, such as dynamic facial expressions, narrative passages or movies, have the potential to accentuate these differences in emotionality, as their understanding requires not only to grasp their meaning but also to access and retrieve their full conceptual representations. Moreover, conceptualizing bilingualism as a continuous and multidimensional phenomenon allowed us to observe more subtle interactive effects of bilingual language background on emotions, that cannot be reduced to a simple effect of language context. Our findings fit well into this new approach to bilingualism, pointing towards bilingualism-related effects that will determine who will show a reduced emotional response.

Our evidence thus advances the current neuroscientific literature on the relationship between language, emotion and bilingualism, providing findings that contribute to our understanding of this dynamic interplay and help guide future research.

5 MATERIALS AND METHODS

5.1 EXPERIMENT 1 (MATERIALS AND METHODS)

5.1.1 Participants

96 young adult volunteers (18 M; age: 24.23 ± 3.58 years; education: 16.69 ± 1.90 years) were enrolled to participate in the study. Sample size was established based on an a priori power analysis run on G*Power 3.1 (Faul et al., 2009) recommending to test at least 84 participants to achieve a statistical power of .80 for a medium effect size of the correlation (.3). Attendees were recruited through word of mouth, flyers and social media, mostly from the University of Milano-Bicocca. All participants were first-language speakers of Italian, who were born and raised in Italy[6]. All participants declared no history of neurological or psychiatric disease, nor currently being in treatment with psychiatric medications, and had normal or corrected-to-normal vision. Participants signed the informed consent after being brief about the experimental procedure. The study was endorsed by the ethical committee of the Psychology Department at the University of Milano-Bicocca (protocol nr.: RM-2023-634).

5.1.2 Assessing vocabulary knowledge

Vocabulary knowledge was evaluated in terms of general and emotion vocabulary sizes, both assessed through a productive and a receptive test. All tests were administered online, with the exception of the free-generation task assessing productive emotion vocabulary.

5.1.2.1 General vocabulary

Productive general vocabulary size was evaluated through 80 general knowledge questions tapping on participants' ability to select a verbal label to express a concept or meaning. Questions varied in difficulty and addressed a wide range of topics, including literature, music, sports, geography, history, science and technology. The 80 items were selected from the Coane and Umanath (2021)'s database: among the original 421 questions, we chose the items that more directly assessed productive word knowledge (rather than general knowledge) (e.g., "What a group of ants is called?" vs. "Which

[6] No data were collected regarding the bilingual language experience of the participants enrolled in Experiment 1.

animal has the widest hearing range?"). Selected questions were then translated into Italian with the help of a proficient bilingual speaker. Participants were asked to choose the correct option from an array of 4 possible alternatives (e.g., What a group of ants is called? 1. Colony; 2. Farm; 3. Hill; 4. Beehive). Both items and their options were presented randomly to participants. Participants were not subjected to any time limit, but were asked to complete the questionnaire within a reasonable time. Productive general vocabulary size was calculated by summing correct responses (score range: 0-80 points).

Participants' receptive general vocabulary size was determined by means of 80 items assessing participants' ability to recognize word meaning. The 80 items were randomly selected from the original 155 item Spanish version of Bermúdez-Margaretto and Brysbaert (2023) and translated into Italian with the help of a proficient bilingual. Each item consisted of a target word and an example of its use in context (e.g., pragmatic [A pragmatic conclusion]). Participants were asked to read each target word and the matching example, and to indicate its meaning by choosing the correct option among 4 possible alternatives. The presentation order of items and their corresponding options was randomized across participants. No temporal pressure was exerted on participants, but they were told to fill in the questionnaire in a suitable time. Productive general vocabulary size was calculated as the sum of correct responses (score range: 0-80 points).

5.1.2.2 Emotion vocabulary

Productive emotion vocabulary size was measured by means of a free-generation task, evaluating participants' ability to generate verbal labels for emotional phenomena. Participants listed as many emotion words, both positive and negative, as they could in two minutes while being recorded (as in Schrauf & Sanchez, 2004). Then, they listened to their own recording and added any other emotion word that came to their mind. Participants were also asked to indicate whether they felt each produced emotion words as being positive, negative or neutral. Words that referred to cognitively driven emotional states (e.g., curious, reflective, suspicious) were discarded. Morphological derivatives of the same word were coded as a single term (e.g., "happiness" and "happy" were both coded as "happy"). Words that seemed to be synonymous (e.g., happy and joyful) were included as different emotion codes as participants may feel them as having a slightly

different meaning. Emotion productive vocabulary size was computed as the sum of the unique emotion words produced.

Receptive emotion vocabulary size was assessed through the Vocabulary of Emotion Test (VET; Costa, Faria & Takšić, 2011) translated into Italian with the help of a proficient bilingual. The test was developed to evaluate the ability to recognize emotional word meanings by means of 35 multiple-choice items, each corresponding to an emotionally charged target-word. Participants were instructed to choose the adjective, from an array of 6 possible alternatives, that best fitted the target word (e.g., "Pessimistic" 1. Hopeless; 2. Joyful; 3. Optimistic; 4. Sad; 5. Insecure; 6. Relieved). Emotion receptive vocabulary size was defined as the sum of correct responses (score range: 0-35 points).

5.1.3 Assessing Trait Emotional Intelligence

The Italian adaptation of the Trait Emotional Intelligence Questionnaire – Short Form (TEIQue-SF; Di Fabio & Palazzeschi, 2011) was used to assess participants' Emotional Intelligence (EI). The TEIQue (Petrides & Furnham, 2004) was originally developed as a 153 item- self-report questionnaire assessing trait EI according to Petrides and Furnham's model (2000). Trait EI was defined as a collection of emotion-related self-perceptions and dispositions related to basic personality dimensions (Petrides & Furnham, 2000) that can be grouped into 15 trait emotional intelligence facets, in turn organized in four main general dimensions (i.e., Well-being, Self-control, Emotionality, and Sociability). In the TEIQue-SF (Petrides, 2009) both trait EI and its four dimensions are operationalised through 30 items, i.e. two items for each of the 15 facets of the TEIQue, for each of which participants are asked to rate their agreement on a 7-point Likert scale (1 = Completely disagree; 7 = Completely agree). The mean of the scores given to each of the 30 items defined participants' trait EI (score range: 1-7 points): the higher the score, the higher participant's emotional intelligence.

For descriptive statistics of participants' vocabulary size and emotional intelligence, see Table 2.

	Mean (SD)	Range
Productive general vocabulary (PVT)	58.115(5.982)	42-72 points
Receptive general vocabulary (RVT)	70.240(5.335)	55-80 points
Productive emotional vocabulary (PEV)	13.729(5.077)	3-33 words
Receptive emotional vocabulary (VET)	28.833(2.642)	20-33 points
Emotional Intelligence (TEIQue)	4.923(0.650)	3.1-6.433 points

Table 2. Participants' Vocabulary and Emotional Intelligence Measures. *Mean, standard deviation (SD) and range are reported for each vocabulary size and emotional intelligence measure. The scores for both the productive and the receptive general vocabularies range from 0 to 80 points. The scores for the receptive emotional vocabulary ranges from 0 to 35 points.*

5.1.4 Stimuli

Experimental stimuli were created from 6 Caucasian identities (3 females and 3 males) displaying happy and fearful faces, selected from the NimStim database (i.e., 01F, 08F, 09F, 20M, 25M, 28M; Tottenham et al., 2009).

Stimuli were manipulated through a morphing technique using PsychoMorph (version 6) (Tiddeman & Perrett, 2001) by moving the fearful face towards the happy face of the same identity by means of 10% steps (i.e., 10% - 20% - 30% - 40% and so on), with the endpoints being 0% = "only fear" and 100% = "only happiness". Following the PsychoMorph manual (Sutherland, 2015), a template was initially defined for both the happy and the fearful face for each identity, placing the fiducial points on facial key features (i.e., eyes, eyebrows, nose, mouth, ears, and outline of the hair). Then, the fearful face was used to manipulate the happy face in 10% steps from "only fear" to "only happiness". Thus, face 1 corresponded to 100% fear and 0% happiness, face 2 to 90% fear and 10% happiness, face 3 to 80% fear and 20% happiness, and so on. A linear continuum (i.e., from "only fear" to "only happiness") composed by 11 morphed faces was created for each of the six identities, yielding 66 morphed faces in total. Faces were cropped in oval shapes to remove hair, ears, backgrounds, and everything below the chin, and presented on a grey screen (RGB: 210, 210, 210) to prevent flickering effects.

Morphed faces used in practice trials were generated from 2 other Caucasian identities (one female and one male) of the NimStim database (i.e., 05F and 41M; Tottenham et al., 2009) following the same procedure described for experimental stimuli.

5.1.5 Procedure

Participants' categorical perception of the fear-to-happiness continuum was evaluated by means of an identification task and a discrimination task. The discrimination task was presented before the identification task to keep participants naïve regarding the use of morphed faces (e.g., Jacques & Caharel, 2022; Cheal & Rutherford, 2011; McCullough & Emmorey; see Fugate, 2013 for a review). Both tasks were implemented in the OpenSesame software (version 3.3.14) (Mathot, Schreij, & Theeuwes, 2012).

5.1.5.1 Identification task

The identification task allowed us to detect both the position of the categorical boundary (i.e., where participants' perception switched from fear to happiness) and the rate of change in categorical perception (i.e., how staedy was the switch from fear to happiness), along the fear-to-happiness linear continuum.

In each trial, after a fixation point presented on a blank screen for 100 ms, followed by a 300 ms blank interval, a morphed face was presented for 900 ms. The inter-trial-interval was jittered between 1100 and 1550 ms (see, Jacques & Caharel, 2022). See Figure 18a, for the trial sequence of the identification task. Participants were asked to identify whether each morphed face portrayed either fear or happiness by pressing a left versus right keyboard key (s, k). The correspondence between stimulus and response was counterbalanced across participants.

The experiment consisted of 6 blocks of 66 trials, each of the morphed images being randomly presented once in each block. Thus, each morphed image was presented six times in the whole identification task. Blocks were separated by an unlimited rest period to prevent fatigue. Before the experiment, participants familiarized with the task by means of 11 practice trials.

5.1.5.2 Discrimination task

The discrimination task allowed us to test the between-category advantage, that is an improved performance for stimuli across the categorical boundary compared to stimuli within the same category (see section 1.6 for a more detail description of the between-category advantage).

In each trial a fixation point was presented randomly for 300, 400 or 500 ms on a blank screen, followed by two consecutive morphed faces (i.e., face A and face B), each presented for 750 ms. Then, a third face (X) appeared on the screen for 1000 ms. A blank screen lasting 1000 ms separated consecutive stimuli (for the same procedure, see McCullough & Emmorey, 2009). Following McCullough and Emmorey (2009), using relatively long ISI and two-step pairings we aimed at maximizing the probability of obtaining categorical perception effects for the discrimination task. See Figure 18b, for the trial sequence of the discrimination task. Participants were instructed to discriminate whether the third one (X) was identical to the first (A) or the second one (B) by pressing the "g" or the "h" keyboard key, respectively.

Faces A and B were always two steps apart along the linear continuum (e.g., image A was 80% happiness-20% fear, and image B was 60% happiness-40% fear; or image A was 50% happiness-50% fear, and image B was 30% happiness-70% fear), resulting in 9 two-step pairings of 11 images for each identity. The third image (X) was identical to image A on half of the trials and to image B on the other half. Each of the nine pairings was arranged into four presentation orders (ABA, ABB, BAA, BAB), generating 36 arrangements for each identity (i.e., 36 arrangements x 6 identities = 216 arrangements in total).

The task was divided in 2 sessions, each comprising two blocks of 108 trials (i.e., 216 trials per session, 432 trials in total). Each of the 36 arrangements per identity was presented twice, once in each session, either in one block or in the other. Specifically, the 216 arrangements were pseudo-randomly divided between the two blocks, as trials included in block a in session 1 were presented in block b in session 2, and vice versa. Within each block the presentation order of trials was randomized. Both sessions and blocks were separated by an unlimited rest period to prevent fatigue. Before the experiment, participants familiarized with the task in 9 practice trials.

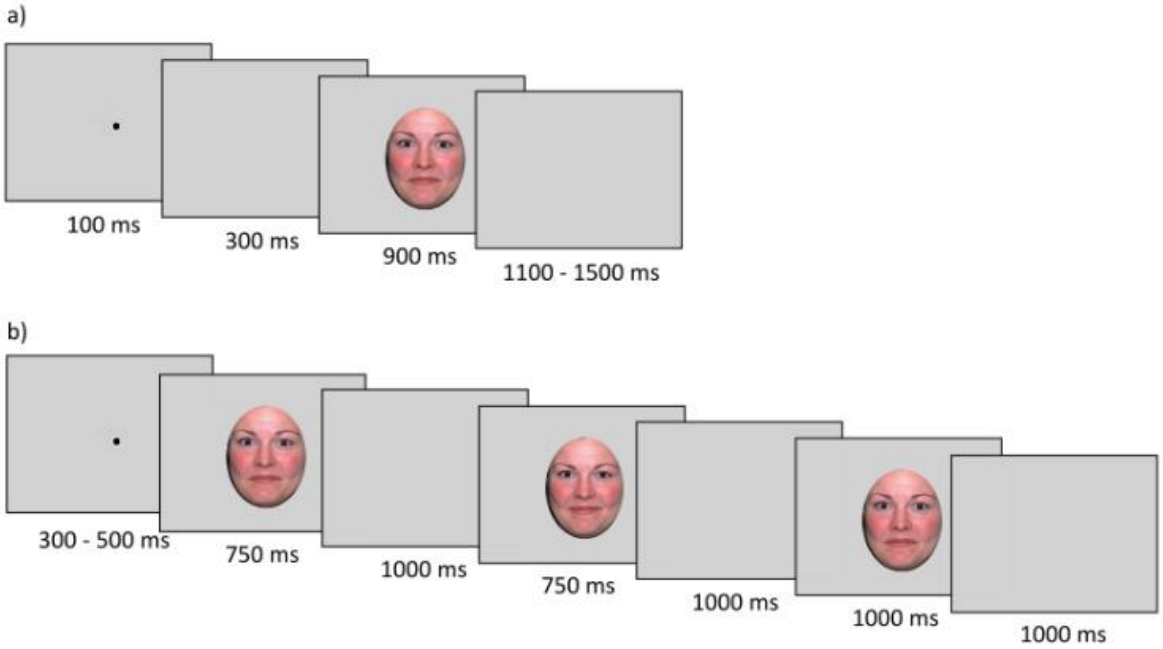


Figure 18. Trial Sequence of the Identification and the Discrimination Tasks. *a) In the identification task, a fixation point was presented on a blank screen for 100 ms, followed by 300 ms of a blank interval. Then, the face target appeared on the center of the screen for 900 ms, followed by a blank screen (1100-1550 ms). Participants indicated whether the target face expressed happiness or fear via a keypress. b) In the discrimination task, a random fixation point was presented on a blank screen (300-500 ms). Then, image A appeared on the screen for 750 ms, followed by 1 second of a blank screen. Image B was presented for 750 ms and image X appeared for 1000 ms after 1 s of blank screen. A fixed ISI lasted for 1000 ms.*

5.1.6 Statistical analyses

R version 4.1.2 (R Core Team, 2021) was used to run all statistical analyses.

First, we tested participants' categorical perception for morphed faces evaluating their performance on both the identification and discrimination tasks.

Then, for each participant the following indexes of categorical perception were extracted to be entered in the correlational analyses: (1) the slope parameter of the psychometric function fitted for identification data, and (2) the beta coefficient estimated for the within-category vs. between-category contrast for discrimination data.

Finally, we investigated the relationship between lexico-semantic knowledge and emotion perception inspecting the correlation between categorical perception and general and emotional vocabulary knowledge. Furthermore, we explored whether emotional perception was associated with participants' emotional intelligence.

5.1.6.1 Identification task

Trials with miss response were discarded from further analyses.

By means of the *quickpsy* R package (Linares & López-Moliner, 2016), we fitted a cumulative probability function plotting the probability of identifying each morphed face as happy against the percentage of happiness involved in it (from 0%, i.e. face 1, to 100%, i.e. face 11). With the *quickpsy* package the Point of Subjective Equivalence (PSE) and the slope parameter of the fitted psychometric function were also estimated. The PSE corresponds to the point along the linear continuum at which a stimulus could equally be classified in either category, setting the categorical boundary. In our case, the PSE stood for the percentage of happiness, from 0% to 100%, where the morphed face had a 50% chance of being categorized as fear and a 50% chance as happy. The slope parameter quantifies the steepness of the fitted function, representing the change rate in participants' categorizations as a function of changing stimulus intensity (Wichmann & Hill, 2001): a steeper slope, associated with lower slope values, indicates a stronger perceptive shift from one category to the other. Parameters corresponding to the probability of guesses and lapses were also estimated.

Then, we evaluated each participant' s categorical perception in the identification task, fitting a psychometric function for each participant and gathering the PSE and slope from each estimated function.

5.1.6.2 Discrimination task

The categorical boundary determined as the PSE of the psychometric function fitted for participants' identification data was used to set both between-category and within-category two-steps apart pairs. Both within-fear and within-happiness pairs were generated. In the between-category pair, morphed faces across the categorical boundary were included, whilst the within-category pairs comprised morphed faces within the same sideway below (i.e., within-fear) or above (i.e., within-happiness) the categorical boundary.

To test the between-category advantage, we run a mixed-effects logistic regression model with AB-pair type (between-category vs. within-category) as predictor and hit

responses as dependent variable. Participants were modelled as random intercept. The *lme4* R package (Bates et al., 2015) was used to fit the model.

Then, we assessed each participant's between-category advantage, running a generalized linear model with AB-pair type as predictor and hit responses as dependent variable and extracting the beta coefficient of the effect of AB-pair type estimated for each model.

5.1.6.3 Correlation between categorical perception, vocabulary size and emotional intelligence

First, Shapiro-Wilk normality tests were performed with the *rstatix* R package (Kassambara, 2023) to assess whether categorical perception, vocabulary knowledge size and emotional intelligence measures were normally distributed.

Then, according to variable distributions, we run either Pearson or Spearman correlations using the *correlation* R package (Makowski et al., 2022). Correlational tests were one-tailed with a significance threshold of $\alpha = 0.05$. Specifically, correlation analyses were left-tailed for slope values as we predicted wider vocabularies/greater emotional intelligence to be associated with higher slope values. Instead, correlations were right-tailed for beta coefficients given a hypothesized association between wider vocabularies/greater emotional intelligence and bigger between-category advantages.

5.2 EXPERIMENT 2 (MATERIALS AND METHODS)

5.2.1 Participants

36 young adult first-language speakers of Italian (L1) who spoke English as a second language (L2) (14 M; age: 24.38 ± 4.21 years; education: 16.85 ± 1.80 years) voluntarily took part in the study. All participants were right-handed as assessed with the Edinburgh Handedness Inventory (Oldfield, 1971) (Edinburgh score: .89 ± .14 points). Participants had no history of neurological or psychiatric disease or substance abuse, nor were currently in treatment with psychiatric medications, and had normal or corrected-to-normal vision. Informed consent was signed by all participants. The study was approved by the Human Research Ethics Committee of the San Raffaele Hospital (Milan, Italy).

5.2.2 Assessing bilingual language profile

Both subjective and objective measures were collected to characterize participants' bilingual language profile.

The Language History Questionnaire (version 3) (LHQ3) (Li et al., 2020) was employed to assess participants' bilingual background, for what concerns L2 AoA, L2 self-reported proficiency, and language dominance. L2 AoA was defined as the lowest age at which participants started using their L2 in speaking, listening, writing or reading. L2 self-reported proficiency was computed as the weighted sum of participants' self-rated proficiency on a 7-point Likert scale (from 1 = "Very poor" to 7 = "Excellent") on listening, speaking, reading, and writing in an L2. Language dominance was calculated, for both L1 and L2, as an aggregate score of the estimated time spent every day using a language and the self-reported proficiency in that language. Then, a L2-L1 dominance score was computed as the ratio of the dominance score of the L2 against that of the L1. The ratio, ranging from 0 to 1, represents the extent to which a participant is exposed to both languages (0 = the participant is exposed only to the L1; 1 = the participant is equally exposed to L1 and L2).

The English Proficiency Test (EPT; developed by Transparent Language, https://www.transparent.com/) was administered to objectively evaluate participants' proficiency in the L2. The EPT is composed of 40 multiple-choice items, 30 evaluating

English grammar and conversational knowledge and 10 assessing text comprehension (EPT scores range: 0–40). Participants were characterized as medium-to-highly proficient according to their EPT scores (35.25 ± 3.59 points; range: 25-40 points). 21 participants (i.e., 58.33%) learned English exclusively in classrooms; 4 participants (i.e., 11.11%) learned English exclusively through immersion; 11 participants (i.e., 30.55%) learned English in mixed contexts (i.e., classroom + self-learning / classroom + immersion / classroom + self-learning + immersion).

For descriptive statistics of participants' bilingual language profile, see Table 3.

	Mean (SD)	Range
L2 AoA	5.69(2.90)	0-11 years
L2 self-reported proficiency	0.74(0.14)	0.43-1
L2-L1 dominance ratio	0.65(0.15)	0.40-0.99
L2 objective proficiency (EPT)	35.34(3.60)	25-40 points

Table 3. Descriptive statistics of bilingual language profile for participants enrolled in Experiment 2*. Mean, standard deviation (SD) and range are reported for L2 age of acquisition (AoA), L2 self-reported proficiency, L2-to-L1 dominance ratio, and L2 objective proficiency (i.e., grammar and conversational knowledge). The scores for L2 self-reported proficiency and L2-to-L1 dominance ratio range from 0 to 1; the score for the L2 objective proficiency ranges from 0 to 40. L2 = second language; L1 = first language.*

5.2.3 Stimuli

Both Italian (L1) and English (L2) words were used as experimental stimuli. For each language, 100 words, i.e. 50 emotionally negative (EWs) and 50 neutral (NWs), were included (200 words in total). L1 words were chosen from the Italian adaptation (Montefinese et al., 2014) of the Affective Norms for English Words database (Bradley & Lang, 1999), whereas L2 words were taken from the Glasgow Norms database (Scott et al., 2019). In each database, words were rated on several psycholinguistic variables, including semantic and affective dimensions (for a more detailed description, see Montefinese et al., 2014; Scott et al., 2019). Both semantic and affective ratings for L1 words were collected on a 9-point Likert scale (from 1 to 9) in Montefinese et al. (2014)' database, whereas L2 words' semantic ratings were gathered on a 7-point Likert scale (from 1 to 7) and affective norms on a 9-point Likert scale (from 1 to 9) in Scott et al. (2019)' database. Within both languages, emotional and neutral words were matched in

terms of semantic ratings but differed in terms of affective dimensions (all *ps* <.001), being emotional words more arousing and less pleasant than neutral ones. Both emotional and neutral words did not differ with respect to affective norms across languages [i.e., L1(EWs) vs L2(EWs) valence: $p = 0.161$; L1(NWs) vs L2(NWs) valence: $p = 0.562$; L1(EWs) vs L2(EWs) arousal: $p = 0.123$; L1(NWs) vs L2(NWs) arousal: $p = 0.171$)]. Nevertheless, L1 and L2 words were statistically different in concreteness (t-value = 2.819, p =.005), and imageability (t-value = 4.548, $p < .0001$), being English words less concrete and imaginable than Italian stimuli, respectively [i.e., L1(EWs) vs L2(EWs) concreteness: $p = .013$; L1(EWs) vs L2 (EWs) imageability: $p < .0001$; L1 (NWs) vs L2 (NWs) imageability: $p = .009$][7].

For descriptive statistics of experimental words' psycholinguistic ratings, see Table 4.

	L1			L2		
	EWs	NWs	*p*	EWs	NWs	*p*
Frequency	39.20	64.39	>.3	44.39	45.92	>.9
OLD	1.55	1.54	>.9	1.81	1.80	>.9
Number of letters	7.04 (1.74)	7.14 (1.95)	>.7	6.26 (2.08)	6.26 (2.10)	>.9
Concreteness	5.63 (1.26)	6.02 (1.87)	>.2	3.87 (1.17)	4.29 (1.47)	>.1
Imageability	6.63 (0.88)	6.68 (1.46)	>.8	4.47 (0.95)	4.54 (1.49)	>.7
Valence	2.21 (0.52)	5.04 (0.27)	<.001	2.06 (0.53)	5.13 (0.27)	<.001
Arousal	6.20 (0.81)	5.03 (0.51)	<.001	5.98 (0.60)	4.80 (1.18)	<.001

Table 4. Psycholinguistic properties of words used in the Emotional Stroop task (EST). *The frequency values for the L1 (Italian) and the L2 (English) were taken, respectively, from*

[7] As semantic ratings for L2 words were gathered on a 7-point Likert scale (from 1 to 7), whereas those for L1 words were collected on a 9-point Likert scale (from 1 to 9), ratings collected on the 7-point Likert scale were translated to the 9-point Likert scale before comparing them.

SUBTLEX_IT and SUBTLEX_UK (http://crr.ugent.be/programs-data/subtitle-frequencies). For each word, the mean Orthographic Levenshtein Distance (OLD) was calculated using the vwr library (https://mran.microsoft.com/snapshot/2019-05-24/web/packages/vwr/index.html) running on R, version 4.1.2. Concreteness, Imageability, Valence, and Arousal scores were taken from the Italian adaptation (Montefinese et al., 2014) of the Affective Norms for English Words (Bradley & Lang, 1999) and the Glasgow norms database (Scott et al., 2019). EWs = emotional words; NWs = neutral words.

5.2.4 Procedure

An Emotional Stroop task (EST) was administered in the MRI scanner with an event-related 2 x 2 (Language: L1, L2; Word Type: NWs, EWs) within-subject design. Participants were instructed to indicate, as quickly and accurately as possible, the ink color of each presented word, without paying attention to the word content. Words were printed in capital letters in red (RGB: 255, 0, 0), blue (RGB: 1, 50, 187), yellow (RGB: 255, 255, 0), or green (RGB: 0, 255, 0). Participants responded by pressing a button on an MRI-compatible response box. Presentation software (http://www.neurobs.com) was used to present stimuli and collect responses. Accuracy and response latencies in milliseconds (ms) were recorded.

Each trial started with a fixation cross presented for 350 ms in the centre of the screen, followed by a 400 ms-blank screen. Then, a word was presented centrally on black background for 2000 ms. The inter-trial interval (ITI) was jittered with Dale's exponential function (mean: 1720.86 ms; range: 1127-3259 ms) (Dale, 1999).

The experimental session was divided into 2 fMRI runs, one per language (L1, L2), each comprising 2 blocks of 100 trials each, with 50 emotional and 50 neutral words (2 runs, 4 blocks, 400 trials in total). Each word was presented twice in each language, once in each block. The same words were printed in two different colours within blocks of the same language condition (i.e., each word was presented in two out of four colours). Moreover, each color was presented 25 times within each block. The 2 fMRI runs were interleaved by the acquisition of a T1w MR image, and their presentation order was counterbalanced across participants. Moreover, trials were arranged in a fixed pseudo-randomized order within each block, with the restriction that no more than 4 subsequent trials belonging to the same condition or having the same colour were presented. Each run lasted approximately 15 minutes (~8 minutes per block). The total scanning time (including the acquisition of structural data) was approximately 45 minutes.

Before completing the EST, participants read standardised instructions and familiarized with the task inside the scanner by means of 56 practice trials (28 trials – 14 emotional, 14 neutral – for each language condition). The words used in the training session were different from experimental stimuli.

At the end of the fMRI session, outside the scanner, participants were asked to rate, on a 7-point scale, the words presented during the fMRI session in terms of valence (from 1 = fully unpleasant to 7 = fully pleasant) and arousal (from 1 = completely calm/relaxed to 7= totally activated). Within each language condition, words were presented in a randomized order, and the order of the language blocks was set to match that of the fMRI session (e.g., participants who were presented first with L1 words also started to evaluate the experimental stimuli in L1). For L2 words, participants were also asked to indicate whether they knew or not the meaning of each word.

5.2.5 MRI Acquisition

A 3 Tesla Philips Ingenia CX MR system (Philips HealthCare, Best, Netherlands) equipped with a 32 channels SENSE head coil was used to acquire MR images at CERMAC (Centro Eccellenza di Risonanza Magnetica ad Alto Campo) of San Raffaele Hospital in Milan (Italy).

A high-resolution T1-weighted MPRAGE (Magnetization Prepared Rapid Gradient Echo) structural image was acquired for each participant (Repetition Time [TR] = 9.9 msec, Echo Time [TE] = 4.9 msec, Flip Angle [FA] = 8°, Field of View [FOV] = 260 mm, matrix size = 256 × 256, number of slices = 243, slice thickness = 1.4 mm, voxel size = 0.7 × 0.7 × 0.7 mm^3 isotropic; Phase Encoding Direction [PE] = R/L; whole brain coverage).

A fast speed Echo Planar Imaging (EPI) sequence (TR = 2000 msec; TE = 33 msec; FA = 85°; number of volumes per run = 218; FOV = 240 x 240 mm; matrix size = 80 x 80; 35 axial slices per volume; slice thickness = 3 mm; interslice gap = 0.75; voxel size = 3 x 3 x 3 mm^3; PE = A/P; SENSE factor = 2; whole brain coverage) was used to acquire functional images. Four dummy scans were acquired before each run to optimize the EPI signal.

5.2.5.1 Pre-processing

MRI data were analysed using SPM12 (https://www.fil.ion.ucl.ac.uk/spm/software/spm12/), running on Matlab 2013b. We first manually set the origin of each T1w image be aligned with the Anterior Commissure – Posterior Commissure (AC-PC) line. Then, T1w images were bias corrected for intensity inhomogeneities and segmented through the ‘‘unified segmentation and normalisation’’ function in SPM12 (Ashburner & Friston, 2005). Non-cerebral tissue was removed from bias-corrected structural T1w images with the “Image Calculator” SPM function. Functional volumes were slice-time corrected using the first slice as reference, then realigned to the first volume and unwarped to correct for motion artefacts and geometric distortions. Realigned functional volumes were coregistered to the bias-corrected skull-stripped structural image and normalised to the standard Montréal Neurological Institute (MNI) template. After normalisation, functional volumes were resampled to 2 x 2 x 2 mm3 voxels and smoothed with a 10 mm full width at half-maximum (FWHM) Gaussian kernel. For each participant, functional volumes were checked for excessive head motion (> 3 mm).

5.2.6 Statistical analyses

5.2.6.1 Behavioral analyses

R software (version 4.1.2) (R Core Team, 2021) was used to run behavioral analyses.

Mixed-effects models were implemented to test the effects of Word Type (i.e., emotional vs. neutral words) and Language (i.e., L2 vs. L1) on RTs, accuracy, valence and arousal ratings[8]. Word Type and Language were entered as fixed effects into the model. Each fixed effect was tested for its significance through likelihood ratio tests, and retained when increasing the goodness of fit of the model. In case of significant interactions, all the lower-order terms involved were retained. Participants and items were modelled as random intercepts. The *emmeans* R package (Length, 2022) was used to compute post-hoc comparisons.

[8] Valence and arousal ratings were collected from 34 out of 36 participants, as two participants were not able to complete the post-fMRI questionnaire.

A linear mixed-effects model was run to analyse RTs, entering raw RTs as dependent variable. A mixed-effects logistic regression model was run to analyse participants' accuracy, specifying correct responses as dependent variable. The *lmerTest* R package (Kuznetsova et al., 2017) was used to implement both models.

Mixed-effects ordinal logistic regression models were implemented with the *ordinal* R package (Christensen, 2019) to analyse valence and arousal rating, with valence or arousal as dependent variable (respectively).

5.2.6.2 fMRI analyses

Functional images were analysed by means of a two-level statistical approach.

First level analysis. We entered the evoked responses for the experimental conditions into a General Linear Model (GLM), modelling them with the canonical haemodynamic response function (HRF). The onset times of the trials were specified for each of the four blocks (i.e., Neutral L1, Emotional L1, Neutral L2, Emotional L2). Realignment parameters were entered as nuisance covariates into the design matrix. Student's t-test linear contrasts were computed for each participant. Main effects of Word type (i.e., Emotional and Neutral) and Language (i.e., L2 and L1) were estimated along with the following contrasts: Word Type [EWs vs. NWs, NWs vs. EWs], Language [L2 vs. L1, L1 vs. L2], and their interactions [L2 NWs vs. L2 EWs, L2 EWs vs. L2 NWs; L1 NWs vs. L1 EWs, L1 EWs vs. L1 NWs; L2 EWs vs. L1 EWs, L1 EWs vs. L2 EWs; L2 NWs vs. L1 NWs, L1 NWs vs. L2 NWs]. Temporal autocorrelation was accounted for with an AR (1) regression algorithm imposing a high-pass filter of 128 s, which removed slow signal chains with a longer period.

Second level analysis. Single-subject contrast images were then entered into a one sample t-test model to test for their significance at the group level. A voxel-wise whole brain analysis was performed. Statistical threshold was set at $p < 0.001$ at the voxel level, and p-family-wise error (FWE) corrected < 0.05 at the cluster level.

5.3 EXPERIMENT 3 (MATERIALS AND METHODS)

5.3.1 Participants

53 young adult first-language speakers of Italian (L1) who spoke English as a second language (L2) (17 M; age: 23.13 ± 2.50 years; education:16.62 ± 1.93 years) voluntarily joined the study. All participants were right-handed as assessed with the Edinburgh Handedness Inventory (Oldfield, 1971) (Edinburgh score: .89 ± .14 points). All participants declared no history of neurological or psychiatric disorders, nor current use of psychiatric medications, and had normal or corrected-to-normal vision. All participants gave their informed consent after being briefed about the experimental procedure. The study was conducted under the approval of the Human Research Ethics Committee of the San Raffaele Hospital (Milan, Italy).

5.3.2 Assessing L2 proficiency

Prior to be enrolled, the L2 proficiency of candidate participants were assessed in terms of their L2 objective proficiency by means of the online English Language Assessment (ELA) developed by Cambridge (https://www.cambridgeenglish.org). The ELA evaluates participants' English grammar and conversational knowledge through 25 multiple-choice questions requiring participants to choose the correct option to fill a sentence. Participants who scored >16/25 points (corresponding to a B1 reference level, as defined by the Common European Framework of Reference for Languages) were retained as eligible participants. No participant was excluded due to a low ELA score. Based on their ELA scores (21.19 ± 2.10 points; range = 17-25 points), participants were classified as medium-to-high proficient.

Due to the audio-visual nature of the task, eligible participants were further tested in terms of their L2 listening proficiency with the upper intermediate difficulty level of the Cambridge First (FCE) Listening (Part 3 - https://www.examenglish.com/FCE/fce_listening3.htm). Participants were asked to listen to five different people talking about a common topic, and then to select the sentence – from a list of 6 – that best described each speaker's opinion on the topic. Participants with a listening proficiency score <3/5 points were discarded. One participant was discarded for this reason, leading to a final sample of 52 medium-to-highly proficient Italian-English bilinguals (17 M; age: 23.21 ± 2.45 years; education: 16.67 ± 1.92 years).

5.3.3 Assessing bilingual language profile

Participants' bilingual profile was assessed through the LHQ3 (Li et al., 2020) with respect to the following dimensions: L2 AoA, L2 subjective proficiency, L2 immersion and L2 exposure. See section 5.2.2 for a detailed description of L2 AoA and L2 subjective proficiency. An aggregate score of L2 immersion was derived from participants' current age, L2 AoA, and years spent using the L2. Daily language exposure was inspected by asking participants to indicate how many hours per day they used each language to speak, listen, read, and write, trying not to exceed 16 hours of total activities, assuming roughly 8 sleeping hours per day. A normalized score for L2 daily exposure was then computed by dividing the total hours per day spent using a language for each activity by 24 (hours). For descriptive statistics of participants' bilingual dimensions, see Table 5.

	Mean (SD)	Range
L2 AoA	5.35(1.34)	0-8 years
L2 objective proficiency (general)	21.21(2.12)	17-25 points
L2 objective proficiency (listening)	4.62(0.63)	3-5 points
L2 self-reported proficiency	0.78(0.09)	0.61-1
L2 immersion	0.75(0.04)	0.62-0.88
L2 exposure	0.14(0.08)	0.01-0.36

Table 5. Descriptive statistics of bilingual language profile for participants enrolled in Experiment 3*. Means (M), standard deviations (SD), and range are reported for participants' measures of L2 background. L2 AoA, L2 immersion, L2 subjective proficiency, and L2 exposure were collected through the LHQ3 (Li et al., 2020). The English Language Assessment (ELA – score range: 0-25) was used to collect L2 general objective proficiency. The Cambridge First (Listening, Part 3) (FCE – score range: 0-5) was used to collect an objective measure of proficiency in L2 listening.*

5.3.4 Stimuli

60 ~1-minute movie clips in their original English (L2) version and their corresponding Italian (L1) dubbed version were used as experimental stimuli (120 clips in total). Movie clips depicted funny, sad, or emotionally neutral dialogic scenes. For each language, 20 clips of each emotion category (i.e., fun, sad, and neutral) were selected. In

the “fun” emotion category, clips contained interpersonal scenes intended to entertain and/or make people laugh; in the “sad” emotion category, clips contained conversations intended to anguish and/or make people cry; in the “neutral” emotion category, clips contained dialogic scenes that were not meant to elicit any particular emotional reaction, either positive or negative. The dialogic scenes considered suitable for eliciting each emotion were selected from popular movies and TV series on online streaming platforms (e.g., Netflix, Prime Video, and Disney+), and cropped using the software OBS Studio (https://obsproject.com/).

A preliminary study was run to assess the emotional valence of the dubbed version of the clips by administering to 33 first-language speakers of Italian a norming questionnaire implemented online. Participants watched each clip and rated on a 7-point Likert Scale (from 1 = “Not at all” to 7 = “Extremely”) the extent to which each of them was perceived as funny, sad, and neutral. Thus, for each clip, three valence ratings were given, one per emotion category. Participants were instructed to watch carefully each clip and to fill in the questionnaire while wearing headphones to ensure greater reliability. A Principal Component Analysis (PCA) showed that all movie clips reliably belonged to the assumed emotion category (for the PCA plot, see Figure A3 - Appendices).

For the purpose of restricting the duration of the scanning session, among the original pool of 60 clips, we selected 36 clips for each language (12 per emotion category) on the basis of their valence norming ratings (i.e., funny, neutral, sad). Therefore, the final experimental pool comprised 72 movie clips (36 in the original English version and 36 in the corresponding Italian version). The mean duration of each clip was 61s (English version: 61.34 ± 2.47 s; dubbed Italian version: 61.40 ± 2.44 s). For the full list of the movie clips, see Table A20 – Appendices.

5.3.5 Procedure

A naturalistic viewing paradigm was implemented in the MRI scanner, presenting participants with fun, sad and neutral movie clips in both dubbed Italian and original English versions. Participants were asked to carefully watch each clip and then to answer a question regarding its content by pressing a button on an MRI-compatible response box with their right hand. Closed-ended questions were intended to ensure both participants’ sustained attention and comprehension throughout the whole task (e.g., “In the videoclip

just presented, did the man believe that their love can work miracles?"). Presentation software (http://neurobs.com) was used to present movie clips and collect participants' responses. Clips were shown onto a screen behind the scanner, and participants could watch them via a mirror on the head coil. The audio was delivered using MRI-compatible headphones. For each participant, audio intensity was adjusted to not be too loud and be heard over the scanner noise.

Two complementary lists of 36 clips were pseudo-randomly generated. In List 1, half of the clips was in the original English version (18 movie clips, 6 per emotional condition - i.e., fun, sad, and neutral), the other half was in the dubbed Italian version. As the clips presented in English in List 1 were presented in Italian in List 2 (and vice versa), each movie clip was shown only once to each participant, either in the L1 or in the L2. Participants were presented with List 1 or List 2 in a counterbalanced order.

In each trial started, a movie clip was presented, immediately followed by a closed question appearing centrally on a blank screen for 3500 ms. Then, a blank screen was presented for a random inter-stimulus interval jittered between 2876, 6149 and 10127 ms.

The task consisted of 2 fMRI runs, one per language, each comprising 2 blocks of 9 trials each, 3 per emotional condition (2 runs, 4 blocks, 36 trials in total). Trials were arranged in a fixed pseudo-randomized order within each block, so that clips extracted from the same movie or TV series were not presented consecutively, and no more than two subsequent clips belonged to the same emotional condition (as in Straube et al., 2010). The two fMRI runs were interleaved by the acquisition of a structural image. Participants familiarized with the task by means of two practice trials, which were not part of the experimental array, presented either in the L1 or in the L2 (depending on the language of the first run). The experimental session in the MRI scanner lasted approximately one hour.

5.3.6 MRI acquisition

MRI images were acquired through a 3T Philips Ingenia CX MR system (Philips HealthCare, Best, Netherlands) equipped with a 32 channels SENSE head coil, at the CERMAC of San Raffaele Hospital in Milan (Italy).

A T1-weighted MR image was acquired for each participant as described in section 5.2.5.

A fast speed EPI sequence (TR = 2000 msec; TE = 33 msec; FA = 85°; number of volumes per run = 320; FOV = 240 x 240 mm; matrix size = 80 x 80; 35 axial slices per volume; slice thickness = 3 mm; interslice gap = 0.75; rec. voxel size = 3 x 3 x 3 mm3; PE = A/P; SENSE factor = 2; whole brain coverage) was used to acquire functional images. Four dummy scans preceded each run to optimize EPI image signal.

5.3.7 Imaging data analyses

MRI data were analysed using SPM12 (https://www.fil.ion.ucl.ac.uk/spm/software/spm12/), running on Matlab 2013b.

Whole-brain activations for emotional and neutral movie clips, within and across languages, were first inspected. We performed a conjunction analysis to identify joint neural underpinnings of emotional processing between bilinguals' two languages, whereas by means of direct contrasts we detected the activations characteristic of each language. Then, in a region-of-interest (ROI) analysis, we narrowed our research focus on the amygdala, testing whether it differentially responded to emotional stimuli presented in a bilingual's two languages. The bilateral amygdala was selected as ROI based on its key role in emotional processing, contributing to both the evaluation and reaction to emotionally salient stimuli (Bujarski et al., 2022; Sergerie et al., 2008; Underwood et al., 2021). Furthermore, neuroimaging studies on bilinguals' emotional processing highlighted an enhanced amygdalar response for emotional stimuli presented in the L1 (e.g., Citron et al., 2020; Hsu et al. 2015; Zheng, Mobbs, & Yu, 2020). Then, we correlated the signal extracted from the bilateral amygdala for clips presented in L2 with measures of participants' bilingual experience (i.e., L2 proficiency, L2 immersion, and L2 exposure) to test whether amygdalar activity was modulated by such measures.

5.3.7.1 Pre-processing

MR images were pre-processed as described in section 5.2.5.1. Note that in this experiment functional volumes were convolved with a 6 mm FWHM Gaussian kernel to minimize inter-subject variability.

5.3.7.2 Whole brain analyses

fMRI data were analysed by means of a two-level statistical approach.

First-level analysis. For each participant a within-subject analysis was performed, modelling the onsets and durations of each emotion category (i.e., fun, sad, neutral) and language (i.e., L1, L2) separately and convolving them with a canonical HRF. Realignment parameters for each session were included as covariates of no interest in the design matrix. The following contrast images of interest were estimated to evaluate the effects of language context (i.e., L1 vs. L2, and L2 vs. L1), emotion category – separately for L1 and L2 (i.e., emotional vs. neutral, fun vs. neutral, sad vs. neutral), and the interactions between language and emotion category (i.e., L1 [emotional vs. neutral] > L2 [emotional vs. neutral], L1 [fun vs. neutral] > L2 [fun vs. neutral], L1 [sad vs. neutral] > L2 [sad vs. neutral], and the corresponding inverse effects). A high-pass filter of 140 s was applied to remove slow signal drifts with a longer period.

Second-level analysis. At the second level the resulting contrast images were tested using one-sample t-tests. Group analyses were thresholded at $p > .001$ at the voxel level, and p-FWE corrected $< .05$ at the cluster level. Moreover, we computed two conjunction analyses to explore the overlapping brain activity between fun and sad movie clips irrespective of language context (i.e., L1 [fun vs. neutral] + L2 [fun vs. neutral], and L1 [sad vs. neutral] + L2 [sad vs. neutral]). Conjunction analyses were thresholded at $p < .005$ at the voxel level, and p-FWE corrected $< .05$ at the cluster level.

5.3.7.3 Region of Interest (ROI) analyses

A spherical ROI analysis was performed with the SPM MarsBar toolbox (Brett et al., 2002). The centres of gravity of all the activation peaks included in the meta-analysis of Sergerie, Chocol, and Armony (2008) were used to set amygdalar coordinates (left amygdala: x = -21, y = -5, z = -16; right amygdala: x = 22, y = -4, z = -15). Then, we created spheres with a 6 mm radius around each locus. Each ROI was used as a mask to extract individual beta weights for [emotional vs. neutral], [fun vs. neutral] and [sad vs. neutral] contrasts across languages. For each subject, a contrast estimate was then computed by averaging the individual beta weights extracted from each voxel of the ROI. Finally, paired-samples t-tests were performed to check for differences between

languages (L1 [emotional vs. neutral] - L2 [emotional vs. neutral]; L1 [fun vs. neutral] - L2 [fun vs. neutral]; L1 [sad vs. neutral] - L2 [sad vs. neutral]; and the inverse effects).

5.3.7.4 Correlation between amygdala response and bilingual language experience

When a significant difference was detected in the ROI analysis, we correlated the contrast estimate extracted from that ROI for the English language (i.e., L2 [emotional vs. neutral], L2 [fun vs. neutral] or L2 [sad vs. neutral]) with bilingual measures of L2 exposure, L2 immersion and L2 objective proficiency (ELA score). Instead of L2 AoA, we decided to include L2 immersion in our analysis as it may be conceived as a dynamic measure of language lifelong exposure considering whether a speaker actively uses or not a language (Li et al., 2020). First, Spearman's correlations were computed among measures of bilingual experience to check for any strong correlation ($r > 0.50$, see, e.g., Taylor, 1990) and avoid multicollinearity (for the correlation matrix, see Figure A4 - Appendices). Then, Spearman correlation analyses between ROI signal and bilingual dimensions were run on R software (version 4.3.0) (R Core Team, 2021) by means of the cor.test function of the *correlation* R package (Makowski et al., 2022). Correlation analyses were two-tailed with a significance threshold of an $\alpha = 0.05$ and corrected for multiple comparisons with Bonferroni correction.

5.4 EXPERIMENT 4 (MATERIALS AND METHODS)

5.4.1 Participants

198 young adult first-language speakers of Italian (65 M; age: 24.89 ± 3.99 years; education: 15.99 ± 2.11 years) were recruited to take part in the study. We randomly assigned 96 participants to the first language condition (L1; Italian), 102 to the second language condition (L2; English). All participants in the L2 condition learnt English as a second language. Participants assigned to the L1 and the L2 condition were matched with respect to age (L1: 24.3 ± 3.67 years; L2: 25.4 ± 4.25 years; W = 5.391, p = 0.076), gender (L1: 61 F, 35 M; L2: 71 F, 27 M; χ^2 = 1.3835, p = 0.23) and education (L1: 15.7 ± 2.13 years; L2: 16.2 ± 2.08 years; W = 5,412, p = 0.061). Informed consent was obtained from all participants. Any information regarding the study was given to all participants in Italian to rule out possible misinterpretations due to the use of the L2. The study was approved by the Human Research Ethics Committee of the San Raffaele Hospital (Milan, Italy).

5.4.2 Assessing bilingual language profile

Both subjective and objective measures of bilingual background for participants assigned to the L2 condition were collected.

Subjective measures of L2 AoA, L2 self-reported proficiency, and language dominance were evaluated through the LHQ3 (see section 5.2.2 for a detailed description of those measures).

The EPT (see section 5.2.2 for a detailed description of the EPT) and a 30-picture naming test were used to compute objective measures of participants' L2 proficiency. In the picture naming test, participants were instructed to name 30 pictures selected from the Snodgrass and Vanderwart (1980)'s dataset to assess participants' L2 vocabulary knowledge (Snodgrass scores range: 0–30 points). The frequency per million of each corresponding word was extracted, and then 10 low-frequency, 10 medium-frequency, and 10 high-frequency words were selected, setting the 30th and 60th percentile, calculated over the pictures' dataset, as cut-offs.

For the descriptive statistics of participants' bilingual profile, see Table 6.

	Mean (SD)	Range
L2 AoA	7.89(3.35)	0-12 years
L2 self-reported proficiency	0.74(0.11)	0.43-1
L2 daily usage	4.52(4.01)	0-18
L2-L1 dominance ratio	0.65(0.11)	0.40-0.99
L2 objective proficiency (EPT)	34.94(3.22)	21-40 points
L2 vocabulary (Snodgrass)	20.81(5.12)	5-30 points

Table 6. Descriptive statistics of bilingual language profile for participants assigned to the L2 condition in Experiment 4*. Means (M), standard deviations (SD), and range are reported for L2 AoA, L2 proficiency, and language dominance. L2 AoA, L2 subjective proficiency, L2 daily usage, and L2-L1 dominance ratio were collected through the LHQ3 (Li et al., 2020). Scores for L2 self-reported proficiency and language dominance range from 0 to 1; scores for L2 proficiency (EPT) range from 0 to 40; scores for L2 vocabulary (Snodgrass) range from 0 to 30. LHQ3 = Language History Questionnaire (version 3); EPT = English Proficiency Test.*

5.4.3 Stimuli

Experimental stimuli consisted of three moral dilemmas (Surgeon, Factory, Bike week; adapted from Cecchetto et al., 2017), and two filler dilemmas (Train or bus, Plant transport; Geipel et al., 2015a) (see Supplementary Materials for the full text).

In moral dilemmas such as *Surgeon*, *Factory*, and *Bike week* people are required to choose between two morally antagonistic options in sacrificial contexts, i.e., killing one person to save a greater number of victims or not killing that person and let the tragedy happen. The first alternative aligns with a utilitarian morality, according to which killing is allowed if it is for a good reason. Conversely, the second alternative aligns with deontological principles, which impose not violating human rights. Moral dilemmas were kept as homogeneous as possible in terms of the potential moderating factors defined by Christensen et al. (2014): Personal Force, Benefit Recipient, Evitability, and Intentionality. All moral dilemmas were personal (i.e., the agent was directly involved in the production of the harm), other-beneficial (i.e., the agent's life was not at risk), avoidable (i.e., the harm was preventable), and instrumental (i.e., the harmful action was not a side-effect). To prevent the emergence of the in-/out-group bias (e.g., Uhlmann et al., 2009; Swann et al., 2010), in all moral dilemmas characters were anonymized, hiding their socio-demographic identity. Furthermore, since the number of potential saved lives

has also been shown to drive people's moral choices (e.g., Cao et al., 2017), it was kept constant from 5 to 7 in both dilemmas, following the categorical distinction proposed by Christensen et al. (2014) (I. 5-10; II. 11-50; III. 100-150; IV. 'thousands' or 'masses' of people). The styling of moral dilemmas, in terms of the relevant information presented (i.e., structure) and the vividness of the language used (i.e., expression style), was also kept as uniform as possible for the three scenarios and their language versions.

Filler dilemmas as *Train or bus* and *Plant transport* require participants to choose between self-interest and common good in non-sacrificial contexts. In the *Train or bus* dilemma, involving a decision between travelling by bus vs. train given certain time constraints, the choice to take the train to attend a meeting on time (i.e., *yes* response) is assumed to induce a high rate of endorsements. In the *Plant transport* dilemma, requiring participants to choose between doing multiple vs. a single car trip to avoid ruining a car's upholstery, the decision to do a single car trip to avoid polluting (i.e., *no* response) is expected to induce a high rate of endorsements (see Brouwer, 2019; Geipel et al., 2015b). If there were language misunderstandings, the rate of yes/no responses should be around chance levels. The percentage of yes responses for *Train or bus* was 96.93% for the L2 condition and 96.87% for the L1 condition. Nevertheless, during data collection, many participants reported not knowing the meaning of a word (upholstery) crucial to understand the *Plant transport* scenario. Therefore, to prevent biases related to poor comprehension, the percentage of responses for this filler dilemma was not analyzed.

The original scenarios were written in English, and then translated into Italian by a proficient bilingual and checked for their consistencies with the original version by two independent judges. The length of both moral and filler dilemmas was kept as equal as possible across the two language versions (i.e., L1 and L2).

5.4.4 Procedure

The experiment was implemented online and presented on a computer screen in the lab to all participants. Participants could fill in all the questionnaires without time pressure, but they were asked to do it within a reasonable time. The experimental session lasted ~15 min for participants in the L1 condition, and ~45 min for participants in the L2 condition due to the additional bilingual measures collected.

Moral and filler dilemmas were presented in a random order across participants, whereas the multiple questions following each dilemma were presented to all participants in a fixed order. Each dilemma included:

(1) a dichotomous question: in moral dilemmas, it required participants whether they would choose to carry out the depicted moral violation (*Do you decide to… yes* = utilitarian response; *no* = deontological response); in filler dilemmas, it asked whether they would choose to carry out the depicted action (*Do you decide to… yes* = self-interest response; *no* = common good response).

(2) a 7-point permissibility rating of the moral violation (*How do you rate this action on a scale from 1 to 7?* 1 = *forbidden*, 4 = *permissible*, 7 = *obligatory*) – only for moral dilemmas.

(3) three 7-point ratings of the perceived emotional distress associated with the scenario just read, each referring to a particular negative emotion or state of being (*Thinking about the scenario I just read, I felt…upset, worried, sad*. 1 = *not at all*, 4 = *somewhat*, 7 = *very much*; from Geipel et al., 2015a) – only for moral dilemmas.

Finally, participants in the L2 condition were requested to rate their understanding of each dilemma on a 7-point scale (*Did you understand the English text in which the problem was presented?* 1 = *not at all*, 4 = *average*, 7 = *very well*). Participants who rated their understanding of at least one moral dilemma as equal or less to 2 were discarded from further analyses. According to such criterion, four participants were excluded, leading to a final sample of 98 participants in the L2 condition and 96 participants in the L1 condition.

5.4.5 Statistical analyses

R (R Core Team, 2021) was used to perform all statistical analyses.

We adopted two complementary analytic approaches to evaluate the effect of using the L2 on participants' morality. First, a between-groups analysis was performed to assess the impact of language condition (i.e., L1 vs. L2) on participants' moral decisions, norm judgment, and emotional distress. Then, a within-group analysis involving participants assigned to the L2 condition only explored whether and what dimension(s)

of bilingual experience (i.e., L2 AoA, L2 proficiency, and Language dominance) influenced the aforementioned outcomes.

5.4.5.1 Between-group analyses

For each moral dilemma, the effect of language condition on moral decisions was assessed through a logistic regression model with type of response (yes/no) as a dependent variable and language condition as predictor.

For each moral dilemma, the effect of language condition on norm judgment was assessed through an ordinal logistic regression with action permissibility ratings as the dependent variable and language condition as predictor. The model was run using *polr* function in the *MASS* library (Venables & Ripley, 2002).

For what concern the perceived emotional distress, the three distress items (upset, worried, and sad) showed a good internal consistency for all moral dilemmas (Cronbach's alpha was 0.87 for *Surgeon*, 0.89 for *Factory*, and 0.91 for *Bike week*), and thus we averaged them to obtain a single emotional distress score. Then, for each moral dilemma, the effect of language condition on perceived emotional distress was assessed through a linear regression with the mean distress rating as dependent variable and language condition as predictor.

5.4.5.2 Within-group analyses

Focusing on participants in the L2 condition, we assessed, for each dilemma, the effect of the different dimensions of bilingual experience on participants' moral decisions, norm judgment, and emotional distress. Before running the analyses, Spearman correlations among bilingual measures were performed to check for any strong correlations ($r > .50$, see, e.g., Taylor, 1990) and thus to avoid multicollinearity (for the correlation matrix, see Figure A5 – Appendices). Accordingly, the following measures were selected as predictors: L2 AoA, L2 proficiency (EPT), and Language dominance. Prior to being included in statistical models, all predictors were centered by subtracting, for each predictor, its mean to each value. Effects were assessed via likelihood ratio tests comparing a model in which the effect of interest was included vs. a model in which it was absent. Effects were retained when increasing the goodness of fit of the model. In case of significant interactions, all the lower-order terms involved were retained.

For each dilemma, the effect of bilingual experience on moral decisions was assessed by running a logistic regression model with type of response (yes/no) as the dependent variable and L2 AoA, L2 proficiency, and Language dominance as predictors.

For each dilemma, the effect of bilingual experience on norm judgment was assessed by running an ordinal logistic regression with the permissibility ratings as the dependent variable and L2 AoA, L2 proficiency, and Language dominance as predictors.

For each dilemma, the effect of bilingual experience on perceived emotional distress was assessed by running a linear regression with the mean distress rating as dependent variable and L2 AoA, L2 proficiency, and Language dominance as predictors.

5.5 EXPERIMENT 5 (MATERIALS AND METHODS)

5.5.1 Participants

339 young adults (105 M; age*:* 25 ± 4.27 years; education: 16.37 ± 2.08 years) were enrolled to participate in the study. Our sample size was determined upon previous FLE studies adopting a continuous approach to bilingualism (e.g., Del Maschio et al., 2022b; Muda et al., 2020; Privitera et al., 2023). All participants were first-language speakers of Italian (L1) and learnt English as a second language (L2). We randomly assigned participants to either a L1 context (Italian; $N = 168$) or a L2 context (English; $N = 171$). Participants did not differ with respect to the matching criteria of age (L1: 24.82 ± 4.11 years; L2: 25.19 ± 4.44 years; W = 15025, $p = 0.462$), gender (L1: 45 M; L2: 60 M, $\chi^2 = 2.357$, $p = 0.125$), and education (L1: 16.15 ± 2.17 years; L2: 16.58 ± 1.97 years; W = 16004, $p = 0.063$). All participants declared no history of neurological or psychiatric disease, nor current treatment with psychiatric medications. All participants signed the informed consent prior to being enrolled. Any information was given to all participants in Italian to avoid possible misunderstandings due to the use of the L2. The study was conducted under the approval of the Human Research Ethics Committee of the San Raffaele Hospital (Milan, Italy).

5.5.2 Assessing bilingual language profile

Participants' bilingual profile was characterized in terms of both subjective and objective measures. Measures of L2 AoA, proficiency, immersion and exposure were subjectively assessed for all participants through the LHQ3, as described in section 5.2.2. Please, note that bilingual language profile was subjectively assessed also for participants assigned to the L1 context to address a limitation of Experiment 4, in which bilingual measures were collected only for participants within the L2 condition. Objective proficiency in the L2 was evaluated only for participants in the L2 context by means of the ELA, as described in section 5.3.2.

5.5.3 Assessing risk-taking attitude and cognitive style

Participants' risk-taking inclination was assessed by means of the Italian adaptation (Fossati et al., 2021) of The Personality Inventory for DSM-5 (PID-5) – Adult (Krueger et al., 2012). Specifically, we used the 14 items pertaining to the personality

trait facet of risk-taking (i.e., items 3, 7, 35, 39, 48, 67, 69, 87, 98, 112, 159, 164, 195, 215). Each item involves a declaration regarding how people may describe themselves in risky situations. Participants were instructed to rate how well each statement described them on a 4-point scale (0 = 'Very false or often false'; 3 = 'Very true or often true'). A risk-taking score was then calculated as the sum of the individual scores on the 14 items (range: 0-42 points). Items 7, 35, 87, 98, 164 and 215 were reverse coded before being entered in the sum. The higher the score, the higher the participants' risk-taking attitude.

Participants' cognitive style was evaluated through the Cognitive Reflection Test (CRT; Frederick, 2005). The CRT is a three-item measure which assesses individual differences in reasoning according to dual-system theories (e.g., Epstein, 1994; Hammond, 1996; Sloman, 1996). Dual-system theories group cognitive processes into two systems: System 1 is responsible of automatic, intuitive, unintentional and quick processes, whereas System 2 manages deliberative, effortful, intentional and slow processes. When facing a judgment or decision-problem, an intuitive answer is immediately returned by System 1, and then checked for its quality by System 2, which, in turns, might approve, adjust, or override it (Kahneman & Frederick, 2002). Each item of the CRT triggers an immediate intuitive but incorrect response, which requires some deliberation to be rejected (see Supplementary Materials for the items of the CRT). Hence, the CRT is thought to evaluate people's ability to engage in reflective thinking to 'override' an incorrect response. The CRT can be scored using different procedures (Erceg & Bubić, 2017). We opted for the CRT-Reflective score, computed as the sum of participants 'correct responses on the three problems, ranging from 0 to 3. This score is supposed to reflect individual differences in reflective thinking (i.e., the ability to reflect upon, and ultimately override, intuitive responses). The higher the score, the more reflective thinking is engaged to answer the problems.

Table 7 reports descriptive statistics of participants' bilingual profile, risk-taking and cognitive style assessment.

	Whole sample (*N* = 339)		NL context (*N* = 168)		FL context (*N* = 171)	
	Mean (SD)	*Range*	*Mean (SD)*	*Range*	*Mean (SD)*	*Range*
Education	16.37 (2.08)	8-24	16.15 (2.17)	8-24	16.58 (1.97)	11-22
L2 AoA	5.92 (2.33)	0-19	5.97 (2.25)	0-19	5.87 (2.41)	0-14
L2 normalized daily Exposure	0.18 (0.17)	0-0.94	0.15 (0.15)	0-0.78	0.21 (0.18)	0-0.94
L2 subjective Proficiency	0.69 (0.17)	0.14-1	0.64 (0.18)	0.14-1	0.74 (0.14)	0.32-1
L2 Immersion	0.73 (0.1)	0.09-0.98	0.71 (0.11)	0.09-0.91	0.74 (0.08)	0.41-0.98
L2 objective Proficiency					17.67 (4.25)	6-25
CRT-Reflective	1.73 (1.17)	0-3	1.59 (1.19)	0-3	1.88 (1.14)	0-3
Risk-taking attitude	17.56 (7.77)	1-41	17.68 (7.93)	1-41	17.44 (7.63)	2-39

Table 7. Descriptive statistics of bilingual language profile, cognitive style, and risk-taking attitude for participants enrolled in Experiment 5*. Means, standard deviations (SD) and range are reported for each measure. L2 Age of Acquisition (AoA), L2 Exposure normalized scores, L2 subjective Proficiency, and L2 Immersion were collected through the Language History Questionnaire (LHQ3). The English Language Assessment (ELA) was used to collect L2 objective Proficiency data from participants assigned to the L2 context. The CRT-Reflective score was computed as the sum of participants' correct responses on the three Cognitive Reflection Test problems, ranging from 0 to 3. Risk-taking attitude was collected through the Italian adaptation of the Personality Inventory for DSM-5 (PID-5).*

5.5.4 Stimuli

Experimental stimuli comprised two moral dilemmas (*Surgeon* and *Bike week*; adapted from Cecchetto et al., 2017) and two exploration-exploitation problems (*Oil*

drilling company and *Broken Glass*; adapted from Mehlhorn et al., 2015) (see Supplementary Materials for the full text).

Both the *Surgeon* and the *Bike week* moral dilemmas were adapted from our previous study (see section 5.4.3 for a broader description). In their original version (Cecchetto et al., 2017), moral dilemmas were formulated as deterministic in nature, as the decision maker can exactly predict the outcome of their decision, knowing the probabilities of all aftereffects for the alternatives (we refer to this version as 'certainty' condition). In order to investigate the effect of uncertainty on morality, the two moral dilemmas were also formulated as non-deterministic in nature, being the decision maker unable to estimate the value of their option and, thus, unaware of the probability of occurrence of each option (we refer to this version as 'uncertainty' condition). The uncertain dilemmas were created by slightly adapting the original risky version of the dilemmas. Indeed, to convey different modal meanings (i.e., necessity vs. possibility), we assigned two different auxiliary verbs (i.e., will/might) to the certain and uncertain versions of each dilemma, respectively (e.g., "(...) If you transplant his organs into the bodies of the other five patients, they (will/might) be saved but the donor (will/might) die" – *Surgeon* dilemma).

In exploration-exploitation problems people are faced with a choice between known and unknown. Keeping on with the already known option that the person is already performing defines exploitation, whereas switching to another unknown option, delving into something new in search of a greater reward, defines exploration. As exploration-exploitation problems inherently involve outcome uncertainty, in both *Oil drilling company* and *Broken glass* scenarios the values associated with the options were not known by the decision-maker. Hence, participants were presented with a single version of each problem. The original English versions of the exploration-exploitation scenarios were translated into Italian by a highly proficient bilingual, and then checked for their consistency by three bilinguals. As with moral dilemmas, the problems were kept as homogeneous as possible in terms of potential moderating factors. Their structure, expression style etc. were kept as homogeneous as possible for all scenarios and their language versions.

Two problem lists were generated for each language (i.e., L1 and L2). In the 'certainty' condition (CC) list, *Surgeon* and *Bike week* were presented in their 'certain' version, together with the *Oil drilling company* and *Broken glass* problems. In the 'uncertainty' condition (UC) list, *Surgeon* and *Bike week* were presented in their 'uncertainty' version, together with the *Oil drilling company* and *Broken glass* problems. Participants within each language context (i.e., L1 and L2) were randomly assigned to either the CC or the UC lists. In the L1 context, 84 participants were assigned to the CC list and 84 to the UC list; in the L2 context, 82 participants were assigned to the CC list and 89 to the UC list. Participants across the 4 lists were matched with respect to age ($\chi^2 = 3.01$, $p = 0.39$), gender ($\chi^2 = 5.92$, $p = 0.12$), and education ($\chi^2 = 5.31$, $p = 0.15$).

5.5.5 Procedure

All questionnaires were administered online to all participants. No time pressure was exerted, but participants were asked to complete all questionnaires at once and in a quiet room.

First, socio-demographic measures were collected for all participants. Then, a problem list (RC or UC, either in L1 or L2) was administered, followed by the LHQ3, the PID-5 and the CRT. The experimental session lasted ~40 min for participants in the L1 condition, and ~55 min for participants in the L2 condition due to the additional ELA measure collected.

Within each list, problems were presented in a random order across participants. After each problem, multiple questions were presented in the same order for all participants:

(1) A dichotomous question – for moral problems, it asked participant whether they would decide to perform the described harmful action (*Do you decide to... yes* = utilitarian response; *no* = deontological response); for exploration-exploitation problems, it asked whether they would choose to remain at an already known option or to give the alternative a try (*Do you decide to…* option 1 = exploitative response; option 2 = explorative response).

(2) A 7-point scale rating the permissibility of the harmful action (*How do you rate this action on a scale from 1 to 7?* 1 = *forbidden*, 4 = *permissible*, 7 = *obligatory*) – this question was only asked for moral dilemmas.

(3) Three 7-point scales rating the emotional distress perceived after reading the dilemma or problem – each scale referred to a particular negative emotion or state of being (*Thinking about the scenario I just read, I felt...upset, worried, sad*. 1 = *not at all*, 4 = *somewhat*, 7 = *very much*; from Geipel et al., 2015).

Finally, participants assigned to the L2 context were required to self-rate the extent to which they understood each dilemma or problem presented in the L2 on a 7-point scale (*Did you understand the English text in which the problem was presented?* 1 = *not at all*, 4 = *average*, 7 = *very well*). A comprehension rate equal or less to 2 in at least one dilemma or problem was set as exclusion criterion. Five participants were excluded from subsequent analyses according to such criterion, leading to a final sample of 168 participants in the L1 context, and 166 in the L2 context. Participants assigned to the L1 and L2 contexts were still matched for age (W = 14723, $p = 0.376$) and gender ($\chi^2 = 2.23$, $p = 0.135$), but were slightly unbalanced with respect to their educational level (W = 15675, $p = 0.045$). Therefore, education was centered and entered as a covariate in the between-group analyses.

5.5.6 Statistical analyses

R software (version 4.3.0) (R Core Team, 2021) was used to run all statistical analyses.

The analytic approach of Experiment 4 was implemented. In a between-group analysis we assessed potential differences in decision-making as a function of language context and problem condition, whereas a within-group analysis tested for potential effects of bilinguals' L2 background on decision-making in a L2. In addition, we inspected potential interactions between significant effects of L2 background and decision-makers' traits (i.e., cognitive style and risk-taking attitude) on decision-making.

5.5.6.1 Between-group analyses

Moral dilemmas. The effects of language context (i.e., L1 vs. L2) and problem condition (i.e., CC vs. UC) on moral decisions, norm judgments, and emotional distress were analysed for each moral dilemma. Participants' (years of formal) education was entered

as a covariate in all statistical models. Interaction terms and main effects were tested as described in section 5.4.5.2.

The effects of language context and problem condition on participants' moral decisions were assessed by means of a logistic regression with type of response (yes vs. no, with yes codifying the utilitarian response) as dependent variable.

The effects of language context and problem condition on participants' norm judgements were assessed by means of an ordinal logistic regression with permissibility ratings as dependent variable (to run the ordinal logistic regression, we used the polr function in the MASS library; Venables & Ripley, 2002).

As the three distress items showed good internal consistency (Cronbach's alpha was 0.85 for Bike week and 0.86 for Surgeon), we averaged them to obtain a single distress score. Then, the effects of language context and problem condition on emotional distress were assessed in a linear regression with the mean distress rating as a dependent variable.

Exploration–exploitation problems. For each exploration-exploitation problem, only the effect of language context was assessed as problems were presented only in one condition. Participants' (years of formal) education was entered as a covariate in all statistical models. Main effects and interactions were tested as described in section 5.4.5.2.

The effect of language context on participants' choices was assessed by means of a logistic regression with type of response (yes vs. no, with yes codifying exploration) as dependent variable.

Since also in this case the three items for emotional distress showed good internal consistency (Cronbach's alpha was 0.84 for Oil drilling company and 0.83 for Broken Glass), they were averaged into a single distress score. The effect of language context on perceived emotional distress was assessed in a linear regression specifying mean distress rating as dependent variable.

5.5.6.2 Within-group analyses

We selected L2 objective Proficiency, L2 normalized Exposure, and L2 Immersion as predictors. We chose L2 Immersion, instead of L2 AoA, as immersion

evaluates active language use for extended periods of time, thus representing a more valid measure of language exposure throughout life than AoA. Before running the analyses, we computed Spearman's correlations among measures of L2 background looking for any strong correlations ($r > 0.50$, see, e.g., Taylor, 1990) to prevent multicollinearity among selected predictors (for the correlation matrix, see Figure A6 – Appendices). L2 Immersion and L2 Proficiency were centered before being entered into statistical models. We first assessed the individual and interactive effects of selected L2 background predictors, then problem condition (CC vs. UC) was added as a further predictor in statistical models. Main effects and interactions were tested as described in section 5.4.5.2.

Moral dilemmas. The effects of L2 background were investigated on moral decisions (by means of a logistic regression), norm judgments (by means of an ordinal logistic regression), and perceived emotional distress (by means of a linear regression).

Exploration–exploitation problems. Exploration–exploitation problems were analyzed through the same procedure of moral dilemmas, with the differences already described in the between-group analysis section.

5.5.6.3 Further analyses

For both dilemmas and problems, we further inspected whether significant effects of L2 background were modulated by participants' risk-taking attitude and cognitive style. When a significant effect of L2 background emerged, the interaction between the L2 variables proved to be significant and participants' traits were tested by entering the PID-5 and the CRT scores in the final model as further predictors. CRT and PID-5 scores were tested in separate analyses. Both the CRT and the PID-5 scores were centered before being entered in statistical models. Main effects and interactions were tested as described in section 5.4.5.2.

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7 APPENDICES

7.1 MATERIALS

7.1.1 Moral dilemmas (Experiment 4)

7.1.1.1 Surgeon (adapted from Cecchetto et al., 2017)

Italian version: “Sei il primario di chirurgia di un ospedale. Cinque dei tuoi pazienti hanno estremo bisogno di trapianti di organi. Ognuno di loro ha bisogno di un organo diverso o morirà. Hai un altro paziente sano che sarebbe un donatore di organi ideale per gli altri. Se trapianti gli organi del donatore nei corpi degli altri cinque pazienti, loro vivranno ma il donatore morirà. Ti avvicini al paziente donatore con l'anestesia e un bisturi. Lui ti supplica terrorizzato di non togliergli la vita”.

English version: “You are the chief surgeon of a hospital. Five of your patients are in dire need of organ transplants. Each of them needs a different organ or they will die. You have another healthy patient who would be an ideal organ donor for the others. If you transplant his organs into the bodies of the other five patients, they will live but the donor will die. You approach the donor patient with anesthesia and a scalpel. He pleads with you terrified not to take his life”.

7.1.1.2 Factory (adapted from Cecchetto et al., 2017)

*Italian version: “*Sei il capo della sicurezza di una fabbrica. Scoppia un incendio e dal sistema di ventilazione esce del fumo. In una stanza della fabbrica ci sono sei dei tuoi operai. In un'altra stanza c'è n’è uno solo. Il fumo si sta dirigendo verso la stanza dei sei operai che moriranno soffocati. Se sigilli il condotto di ventilazione che porta alla stanza dei sei operai, loro saranno al sicuro ma l’operaio nell'altra stanza morirà a causa del fumo che hai deviato. Stai per sigillare il condotto. Dalle videocamere di sorveglianza guardi l’operaio nell’altra stanza mentre piangendo ti implora di risparmiargli la vita”.

English version: “You are the head of security of a factory. A fire breaks out, and there is smoke coming through the ventilation system. In one room of the factory there are six of your workers. In another room there is only one. The smoke is heading towards the room of the six workers who will die of suffocation. If you manually seal the ventilation duct that leads to the six workers' room, they will be safe but the worker in the

other room will die from the diverted smoke. You're about to seal the duct. From the video surveillance you watch the worker in the other room who cries and begs you to spare his life".

7.1.1.3 Bike week (adapted from Cecchetto et al., 2017)

Italian version: "Sei un motociclista esperto e stai partecipando ad un evento con alcuni amici. Mentre stai guidando davanti ad un gruppo di sette motociclisti, noti che un motociclista di fianco a te ha un pneumatico difettoso che sta per scoppiare. Questo provocherà un tamponamento a catena, causando la morte dei sette motociclisti dietro di voi. Se spingi il motociclista fuori strada, gli altri sette dietro di voi saranno salvi ma il motociclista morirà. Alzi la gamba per speronarlo. Lui ti guarda spaventato e ti urla di non colpirlo".

English version: "You are an experienced biker and you are attending an event with some friends. While you are riding in front of a group of seven bikers, you notice that a rider next to you has a faulty tire that is about to burst. This will cause a rear-end collision, killing the seven riders behind you. If you push the rider off the road, the other seven behind you will be safe but the rider will die. You raise your leg to ram him. He looks at you scared and yells at you not to hit him".

7.1.2 Filler dilemmas (Experiment 4)

7.1.2.1 Train or Bus (Geipel, Hadjichristidis & Surian, 2015)

Italian version: "Devi viaggiare da Milano a Roma per partecipare a una riunione che inizia alle 14:00. Puoi prendere il treno o l'autobus. Il treno ti porterà lì giusto in tempo per il tuo incontro, qualunque cosa accada. L'arrivo dell'autobus è previsto un'ora prima della riunione, ma a volte è in ritardo di diverse ore a causa del traffico. Sarebbe bello avere un'ora in più prima della riunione, ma non puoi permetterti di arrivare in ritardo".

English version: "You need to travel from Milan to Rome in order to attend a meeting that starts at 2:00 PM. You can take either the train or the bus. The train will get you there just in time for your meeting no matter what. The bus is scheduled to arrive an hour before your meeting, but the bus is occasionally several hours late because of traffic.

It would be nice to have an extra hour before the meeting, but you cannot afford to be late".

7.1.2.2 Plant Transport (Geipel, Hadjichristidis & Surian, 2015)

Italian version: "Stai portando a casa un certo numero di piante da un negozio che si trova a circa 5 chilometri da casa tua. Il bagagliaio della tua auto, che hai rivestito di plastica per raccogliere il fango dalle piante, conterrà la maggior parte delle piante che hai acquistato".

English version: "You are bringing home a number of plants from a store that is about 5 kilometers from your home. The trunk of your car, which you have lined with plastic to catch the mud from the plants, will hold most of the plants you have purchased".

7.1.3 Moral dilemmas (Experiment 5)

For the certain versions of the both the Surgeon and the Bike week dilemmas see sections 7.1.1.1 and 7.1.1.3, respectively.

7.1.3.1 Uncertain version of the Surgeon dilemma (adapted from Cecchetto et al., 2017)

Italian version: "Sei il primario di chirurgia di un ospedale. Cinque dei tuoi pazienti hanno estremo bisogno di trapianti di organi. Ognuno di loro ha bisogno di un organo diverso o rischia di morire. Hai un altro paziente sano che è un donatore di organi ideale per gli altri. Se trapianti gli organi del donatore nei corpi degli altri cinque pazienti, loro potrebbero salvarsi ma il donatore potrebbe morire. Ti avvicini al paziente donatore con l'anestesia e un bisturi. Lui ti supplica terrorizzato di non togliergli la vita".

English version: "You are the chief surgeon of a hospital. Five of your patients are in dire need of organ transplants. Each of them needs a different organ or they might die. You have another healthy patient who is an ideal organ donor for the others. If you transplant his organs into the bodies of the other five patients, they might live but the donor might die. You approach the donor patient with anaesthesia and a scalpel. He pleads with you terrified not to take his life".

7.1.3.2 Uncertain version of the Bike week dilemma (adapted from Cecchetto et al., 2017)

Italian version: “Sei un motociclista esperto e stai partecipando ad un evento con alcuni amici. Mentre stai guidando davanti ad un gruppo di sei motociclisti, noti che un motociclista di fianco a te ha un pneumatico difettoso che potrebbe scoppiare. Questo provocherebbe un tamponamento a catena, causando la morte dei sei motociclisti dietro di voi. Se spingi il motociclista fuori strada, gli altri sei dietro di voi potrebbero salvarsi ma il motociclista potrebbe morire. Alzi la gamba per speronarlo. Lui ti guarda spaventato e ti urla di non colpirlo”.

English version: “You are an experienced biker, and you are attending an event with some friends. While you are riding in front of a group of six bikers, you notice that a rider next to you has a faulty tire that might burst. This might cause a rear-end collision, killing the six riders behind you. If you push the rider off the road, the other six behind you might be safe but the rider might die. You raise your leg to ram him. He looks at you scared and yells at you not to hit him”.

7.1.4 Exploration-exploitation problems

7.1.4.1 Oil drilling company problem

Italian version: “Sei stato appena assunto in una società di trivellazione petrolifera. Vieni pagato in base a quanto petrolio riesci ad estrarre. Se non estrai abbastanza petrolio, rischi il licenziamento. Trovarsi nuovamente disoccupato sarebbe molto grave, perché hai una famiglia numerosa da mantenere. Hai accesso a due siti di trivellazione, ma puoi usarne solo una alla volta. Il primo giorno non conosci i siti di trivellazione, quindi ne scegli uno a caso e inizi a lavorare. Dopo cinque estrazioni soddisfacenti, il sito che hai scelto produce una quantità di petrolio insufficiente”.

English version: “You just got hired at an oil drilling company. You get paid based on how much oil you can extract. If you don't extract enough oil, you risk being fired. Finding yourself unemployed again would be very serious, because you have a large family to feed. You have access to two drilling sites, but you can only use one at a time. The first day you don't know the drilling sites, so you choose one at random and start working. After five satisfactory extractions, the site you chose produces insufficient oil”.

7.1.4.2 Broken glass problem (adapted from Mehlhorn et al., 2015)

Italian version: “Hai accettato da poco un nuovo lavoro in una fabbrica di bicchieri. Vieni pagato in base a quanti bicchieri integri riesci a produrre. Se non produci abbastanza bicchieri integri, rischi di essere licenziato. Perdere anche questo lavoro sarebbe molto grave, perché hai una madre malata che ha bisogno di cure costose. Hai accesso a due macchine che producono bicchieri, ma puoi usarne solo una alla volta. Il primo giorno non sai nulla delle due macchine, quindi ne scegli una a caso e inizi a lavorare. Dopo sei bicchieri integri, la macchina che hai scelto ne produce uno rotto”.

English version: “You recently took a new job in a glass factory. You get paid based on how many undamaged glasses you can produce. If you don't produce enough undamaged glasses, you risk being fired. Losing this job too would be very serious, because you have a sick mother who needs expensive care. You have access to two machines that make glasses, but you can only use one at a time. The first day you know nothing about the two machines, so you pick one at random and start working. After six undamaged glasses, the machine you have chosen produces a broken one”.

7.1.5 Cognitive Reflection Test (CRT; Frederick, 2005)

(1) A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? ___ cents. (correct response = 5 cents; intuitive response = 10 cents).

(2) If it takes 5 machines 5 min to make 5 widgets, how long would it take 100 machines to make 100 widgets? ___ min. (correct response = 5 min; intuitive response = 100 min).

(3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ___ days. (correct response = 47 days; intuitive response = 24 days).

7.2 FIGURES

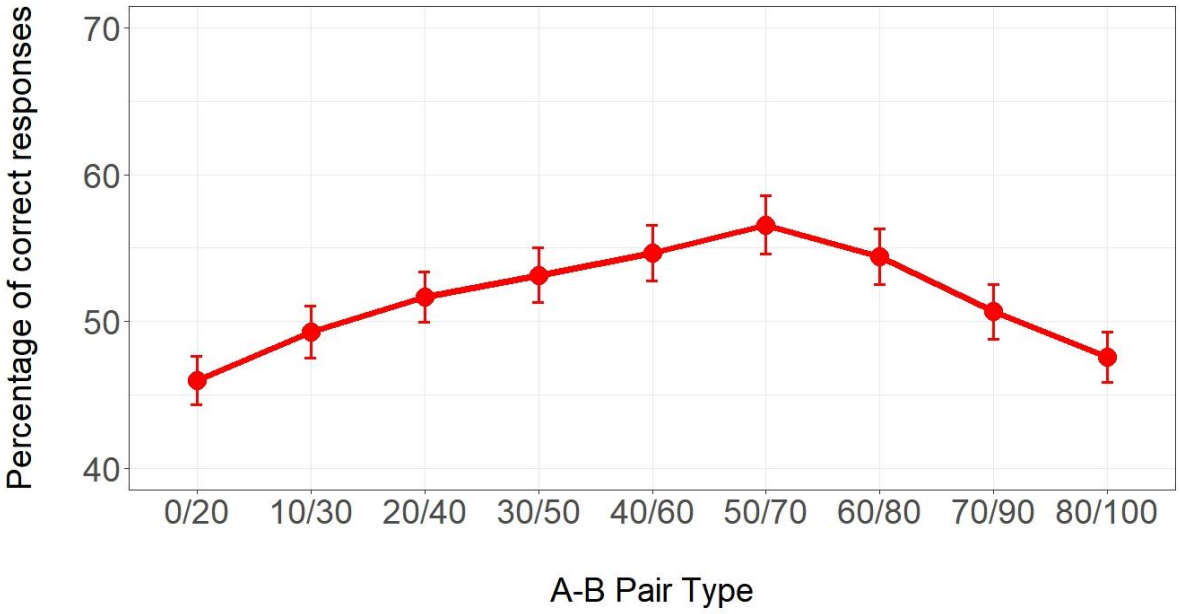


Figure A1. Participants' discriminative accuracy across all Image A – Image B pairs. *Predicted probabilities of correct responding in the ABX discrimination task are represented for each of the nine AB-pair types. Red dots indicate the point estimates, whereas red lines stand for the error bars. The number to the left of the slash represents the percentage of happiness in image A, the number to the right of the slash the percentage of happiness in image B.*

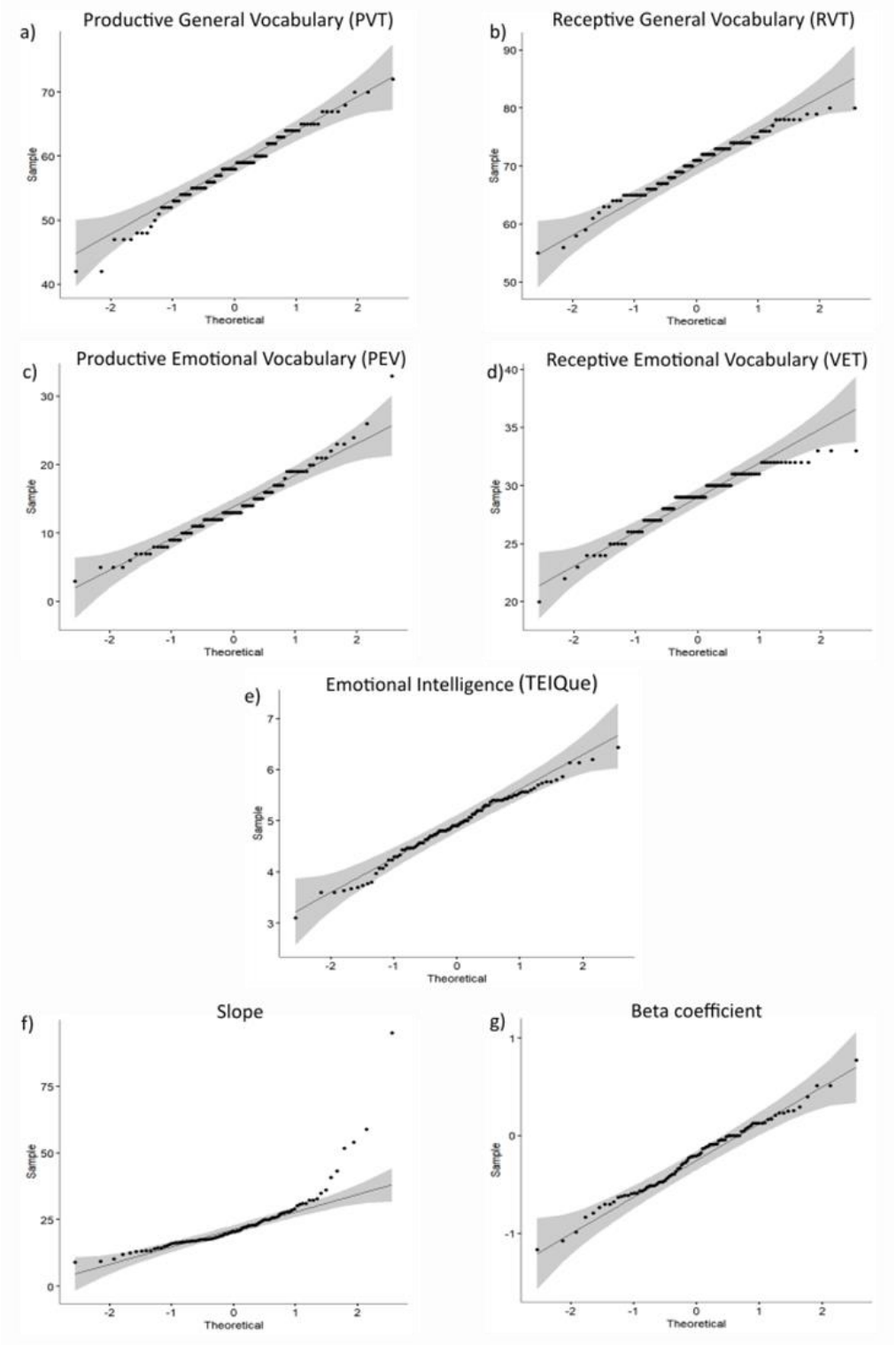


Figure A2. Q-Q plots for Measures of Categorical Perception, Vocabulary Size and Emotional Intelligence. *Quantile-Quantile (Q-Q) plots are represented for participants' (a) productive general vocabulary (PVT) (W = .985, p = .348), (b) receptive general vocabulary (RVT) (W = .974, p = .053), (c) productive emotional vocabulary (PEV) (W = .968, p = .020), (d) receptive emotional vocabulary (VET) (W = .941, p = .0003), and (e) emotional intelligence (TEIQue) (W = .986, p = .421) scores. Q-Q plots are also shown for participants' (f) slope values (W = .717, p < .0001) and (g) estimated beta coefficients (W = .991, p = .773).*

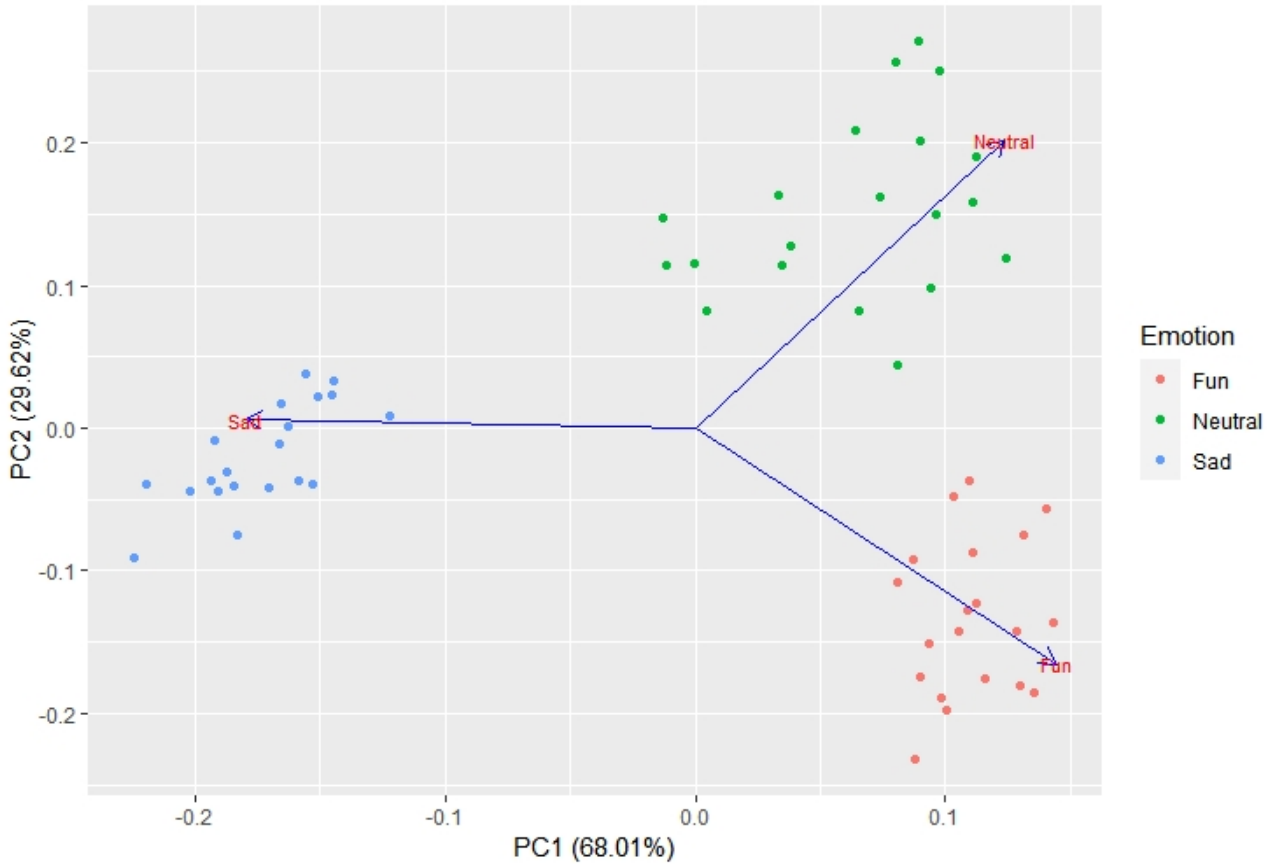


Figure A3. Principal Component Analysis (PCA) biplot of the 20 Italian videoclips. *The PCA biplot displays both scores and loading vectors. Each dot represents an Italian videoclips. The axes show the principal component scores, and the vectors (in blue) are the loading vectors. Each loading vector represents the loading pair per original variable. Videoclips that belong to the same emotion category are located closer to each other, that is they have similar principal component scores. The vector projections on the PC1 axis reveals both the direction and the strength of the association between each emotion category and PC1, whereas the vector projections on the PC2 axis show the associations between each emotion category and PC2. Figure A3 was taken from Bellini et al. (2024) (https://doi.org/10.1016/j.bandl.2024.105424).*

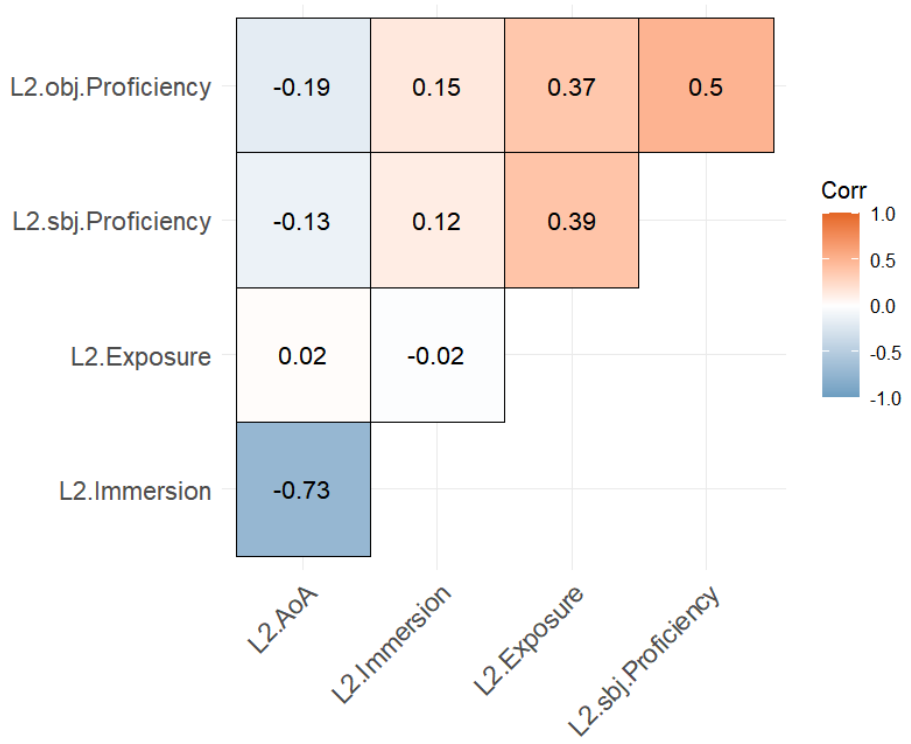


Figure A4. Correlational matrix between objective and subjective measures of L2 bilingual language background (Experiment 3). *Negative correlations are displayed in blue, while positive correlations in red colour. Colour intensities are proportional to the Spearman correlation coefficients. In the right side of the correlogram, the legend colour shows the correlation coefficients and the corresponding colours. Rho values are reported. L2 AoA, L2 subjective proficiency, L2 exposure, and L2 immersion are obtained by the LHQ3 (Li et al., 2020). L2 general proficiency is the result of the English Language Assessment (ELA). AoA = age of acquisition; obj = objective; sbj = subjective. Figure A4 was adapted from Bellini et al. (2024) (* https://doi.org/10.1016/j.bandl.2024.105424*).*

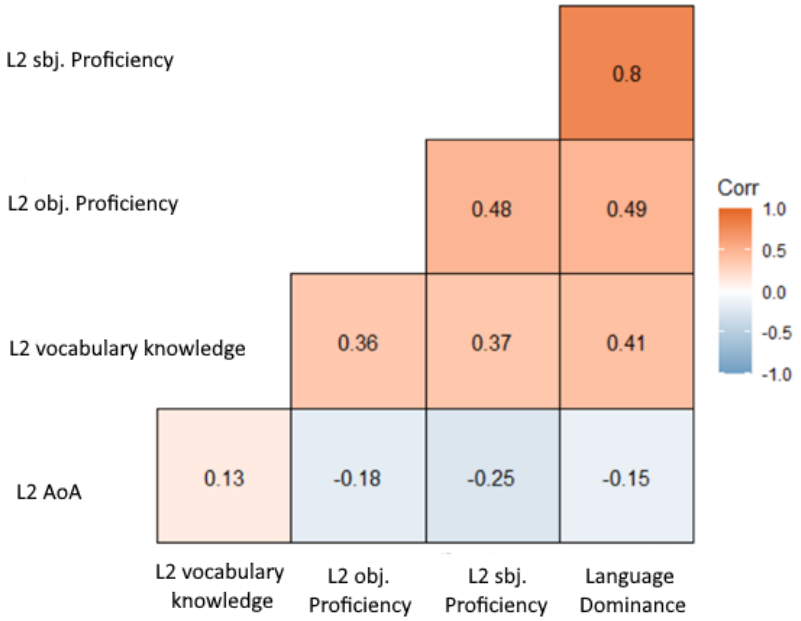


Figure A5. Correlational matrix between objective and subjective measures of L2 bilingual language background (Experiment 4). *Spearman's correlation coefficients (ρ) between measures of bilingual language background are reported. Negative correlations are displayed in blue, while positive correlations in red colour. Colour intensities are proportional to the Spearman correlation coefficients. In the right side of the correlogram, the legend colour shows the correlation coefficients and the corresponding colours. Rho values are reported. L2 AoA, L2 subjective proficiency, and language dominance were obtained from the LHQ3 (Li et al., 2020). L2 objective proficiency is the result of the English Proficiency Test (EPT), whereas L2 vocabulary knowledge results from the Snodgrass Test. L2 = second language; AoA = age of acquisition; obj = objective; sbj = subjective. Figure A5 was adapted from Del Maschio et al. (2022b) under the terms of the Creative Commons Attribution License (CC BY) (https://doi.org/10.1017/langcog.2022.14).*

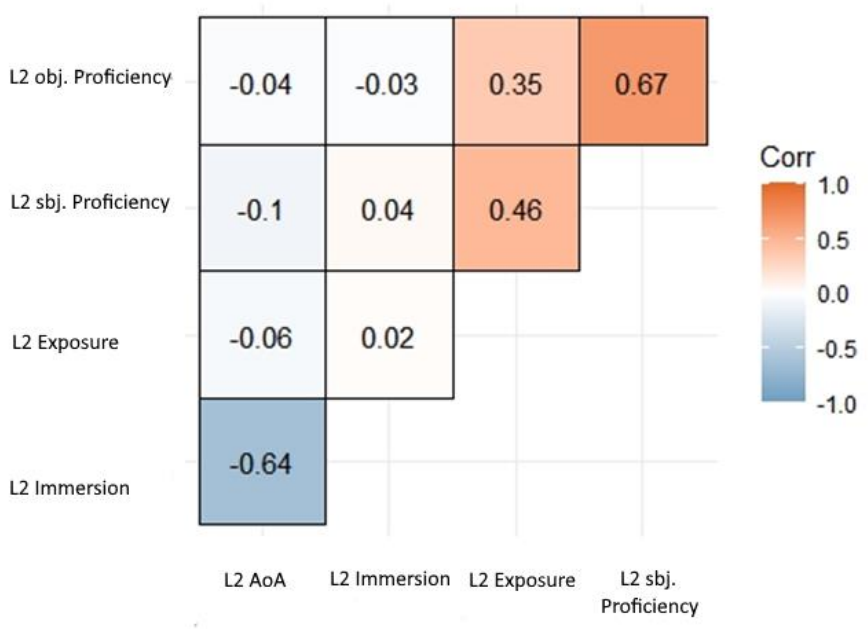


Figure A6. Correlational matrix between objective and subjective measures of L2 bilingual language background (Experiment 5). *Spearman's correlation coefficients (ρ) between measures of bilingual language background are represented. Negative correlations are displayed in blue, while positive correlations in red colour. Colour intensities are proportional to the Spearman correlation coefficients. In the right side of the correlogram, the legend colour shows the correlation coefficients and the corresponding colours. Rho values are reported. L2 AoA, L2 subjective proficiency, L2 exposure and L2 immersion were obtained from the LHQ3 (Li et al., 2020). L2 objective proficiency is the result of the English Language Assessment (ELA). L2 = second language; AoA = age of acquisition; obj = objective; sbj = subjective. Figure A6 was adapted from Del Maschio et al. (submitted).*

7.3 TABLES

Contrast	p - FWE	k	t-value	Hem	Labels (AAL)	MNI coordinates		
						x	y	z
NWs > EWs	0.007	697	4.98	L	Putamen	-20	8	14
			4.20	L	Putamen	-26	-14	2
			4.15	L	Thalamus	-22	20	-2
	< 0.0001	1276	4.48	L	PostCentral Gyrus	-44	-10	44
			4.13	L	PreCentral Gyrus	-28	-16	60
			4.09	L	Middle Cingulum	-14	6	44
L2 NWs > L2 EWs	< 0.0001	2041	5.09	L	Superior Frontal Cortex	-20	8	44
			4.42	L	PreCentral Gyrus	-30	-20	56
			4.23	L	PostCentral Gyrus	-38	-32	56
	0.009	620	4.56	L	Thalamus	-12	-24	8
			4.49	L	Thalamus	-20	-14	4
			4.23	L	Thalamus	-24	-26	8
L1 EWs > L2 EWs	0.043	317	5.65	L	Thalamus	-20	-30	8
			4.78	L	Thalamus	-12	-24	8
			3.55	L	Thalamus	-12	-16	4
	< 0.0001	1276	4.66	R	Posterior Cingulate Cortex	2	-36	32
			4.65	L	Precuneus	-16	-54	40
			4.55	L	Angular Gyrus	-22	-50	36

Table A1. Contrast analyses (Experiment 2). *Contrasts leading to significant effects (voxel-level: p < 0.001 uncorrected; cluster-level: p-FEW < 0.05). k = number of voxels within each significant cluster. Hem = hemispheric lateralization. Coordinates (x, y, z) are reported in MNI space. Region labels are based on the Harvard-Oxford Atlas. L1 = first language; L2 = second language; EWs = emotional words; NWs = neutral words.*

Contrast	p-FWE	k	t-value	hemisphere	Labels (AAL)	MNI coordinates		
						x	y	z
L1 [fun vs. neu] + L2 [fun vs. neu]	< 0.0001	17094	9.29	L	Middle Temporal Cortex	-48	-54	12
			8.28	L	Middle Temporal Cortex	-54	-48	12
			8.02	R	Superior Temporal Cortex	64	-44	18
	0.002	654	6.27	L	Precuneus	-4	-50	46
			5.02	R	Precuneus	8	-54	46
	< 0.0001	899	5.40	L	Inferior Frontal Cortex Pars Opercularis	-52	16	18
			4.90	L	Inferior Frontal Cortex Pars Opercularis	-54	14	10
	0.001	823	4.49	L	Inferior Frontal Cortex Pars Triangularis	-52	20	2
			5.38	R	Inferior Frontal Cortex Pars Triangularis	58	22	6
			4.56	R	Inferior Frontal Cortex Pars Triangularis	46	30	0
			3.97	R	Inferior Frontal Cortex Pars Triangularis	52	18	20
L1 [sad vs. neu] + L2	< 0.0001	776	4.58	R	Middle Occipital Cortex	30	-78	18
			4.57	R	Superior Occipital Cortex	26	-74	36
			3.80	R	Superior Parietal Lobe	22	-62	58

[sad vs. neu]								
L1 emo vs. L2 emo	< 0.0001	1655	6.74	L	Inferior Temporal Cortex	-44	-2	-44
			6.43	L	Middle Temporal Cortex	-60	-12	-10
			6.41	L	Middle Temporal Cortex	-54	-4	-18
	0.002	307	4.67	L	Middle Temporal Cortex	-46	-56	20
			4.55	L	Angular Gyrus	-38	-58	24
			3.84	L	Angular	-52	-60	26
L1 fun vs. neu	< 0.0001	19726	11.29	L	Middle Temporal Cortex	-48	-60	12
			10.88	L	Fusiform Gyrus	-42	-48	-20
			10.80	L	Middle Occipital Cortex	-50	-72	10
			9.32	R	Inferior Frontal Cortex Operculum	56	14	16
		1992	8.03	R	Inferior Frontal Cortex pars Triangularis	52	28	2
			6.85	R	PreCentral Gyrus	50	4	48
	< 0.0001	1032	8.24	L	Inferior Frontal Cortex Operculum	-52	10	22
			5.32	L	Inferior Frontal Cortex Operculum	-42	10	18

			4.99	L	Inferior Frontal Cortex pars Triangularis	-50	20	0
			7.85	L	Precuneus	-4	-52	44
	< 0.0001	710	6.26	R	Precuneus	6	-52	44
			5.42	L	Precuneus	-4	-58	58
			5.91	R	Supplementary Motor Area	10	12	62
	< 0.0001	325	4.47	L	Supplementary Motor Area	-4	22	58
			6.62	R	Superior Occipital Cortex	28	-78	44
	< 0.0001	1030	5.78	R	Superior Occipital Cortex	26	-74	34
			5.14	R	Superior Parietal Lobe	14	-80	50
			6.61	L	Superior Occipital Cortex	-24	-78	34
	<							
L1 sad vs. neu	0.0001	744	5.96	L	Superior Occipital Cortex	-18	-78	46
			5.74	L	Middle Occipital Cortex	-28	-80	5
			5.65	R	Fusiform Gyrus	36	-56	-8
	0.001	288	4.97	R	Inferior Temporal Cortex	52	-52	-6
			4.42	R	Inferior Temporal Cortex	42	-62	-8
	<		5.28	R	Middle Cingulum	12	-38	40
	0.0001	531	4.98	R	Middle Cingulum	10	-24	32

			4.16	R	Posterior Cingulum	7	-34	30
	0.01	190	4.88	L	Inferior Temporal Cortex	-56	-58	-6
			4.48	L	Inferior Occipital Cortex	-44	-66	-6
			10.16	L	Fusiform Gyrus	-38	-56	-12
	< 0.0001	7629	9.46	L	Middle Temporal Cortex	-48	-54	10
			8.38	L	Fusiform Gyrus	-42	-46	-22
			8.47	R	Middle Temporal Cortex	56	4	-18
	< 0.0001	5976	8.39	R	Middle Temporal Cortex	46	-46	16
			8.00	R	Superior Temporal Cortex	64	-44	18
L2 fun vs. neu	< 0.0001	398	6.36	R	Cerebellum Crus II	22	-78	-36
			3.93	R	Cerebellum Crus II	8	-78	-42
			3.44	R	Cerebellum Crus I	14	-74	-26
			6.10	L	Inferior Frontal Cortex Operculum	-48	18	18
	< 0.0001	635	6.06	L	Inferior Frontal Cortex Operculum	-56	18	14
			5.81	L	Inferior Frontal Cortex pars Orbitalis	-44	26	-12
	< 0.0001	410	5.73	R	Inferior Frontal Cortex Operculum	56	20	8

			5.13	R	Inferior Frontal Cortex pars Triangularis	56	28	10
			4.87	R	Inferior Frontal Cortex pars Triangularis	58	22	18
	< 0.0001	435	5.69	L	Precuneus	-4	-50	48
			4.89	R	Precuneus	6	-54	46
	0.024	171	5.00	R	PreCentral Gyrus	40	0	44
			4.76	R	Middle Frontal Cortex	44	2	54
	0.008	215	4.97	L	PreCentral Gyrus	-36	-4	54
L2 sad vs. neu	0.032	149	5.35	R	Middle Occipital Cortex	30	-80	18
			4.63	R	Middle Occipital Cortex	38	-80	16
			3.73	R	Middle Occipital Cortex	36	-76	8
	0.049	133	4.55	R	Superior Parietal Lobe	30	-52	62
			4.20	R	Superior Parietal Lobe	22	-58	58
	0.027	154	4.39	L	Middle Occipital Cortex	-26	-84	18
			4.37	L	Middle Occipital Cortex	-32	-82	8
L1 [fun vs. neu] > L2 [fun vs. neu]	0.001	316	5.12	R	Superior Temporal Cortex	58	-28	8
			5.05	R	Superior Temporal Cortex	58	-14	-2
			3.38	R	Superior Temporal Cortex	48	-28	6

Table A2. Contrast analyses (Experiment 3). *Contrasts yielding significant clusters of activation (voxel-level: p < 0.001 uncorrected; cluster-level: p-FEW < 0.05). Region labels are taken from the Harvard-Oxford. Stereotactic coordinates (x, y, z) are reported in MNI space. k = number of voxels within each cluster; L = left; R = right; L1 = Italian; L2 = English; neu = neutral; emo = emotional (fun + sad).*

Effects	b	SE	z	p value
Intercept	-1.37	0.31	-4.40	<.001
Proficiency	-0.17	0.38	-0.44	.65
AoA	-0.23	0.32	-0.72	.47
Dominance	-0.15	0.39	-0.39	.69
Proficiency X AoA	0.07	0.43	0.18	.85
Proficiency X Dominance	-0.32	0.46	-0.70	.48
Dominance X AoA	-0.80	0.38	-2.10	.03
Proficiency X Dominance X AoA	1.43	0.68	2.08	.03

Table A3. Effects of bilingual language background on moral decisions in the Surgeon dilemma (Experiment 4). *Parameters of the final model for the analyses of the moral decision (i.e., number of utilitarian choices) for the Surgeon dilemma. SE = standard error.*

Effects	b	SE	z	p value
Intercept	0. 71	0.22	3.22	.001
Proficiency	-0.35	0.26	-1.33	.18
AoA	0.16	0.22	0.72	.46
Dominance	0.44	0.27	1.66	.09

Table A4. Effects of bilingual language background on moral decisions in the Factory dilemma (Experiment 4). *Parameters of the final model for the analyses of the moral decision (i.e., number of utilitarian choices) for the Factory dilemma. Note. SE = standard error.*

Effects	b	SE	z	p value
Intercept	-0.29	0.20	-1.44	.15
Proficiency	0.003	0.23	0.01	.98
AoA	0.36	0.22	1.62	.10
Dominance	0.02	0.23	0.11	.90

Table A5. Effects of bilingual language background on moral decisions in the Bike week dilemma (Experiment 4). *Parameters of the final model for the analyses of the moral decision (i.e., number of utilitarian choices) for the Bike week dilemma. SE = standard error.*

Effects	b	SE	t	p value
Proficiency	-0.17	0.19	-0.90	.36
AoA	0.08	0.19	0.45	.65
Proficiency X AoA	-0.45	0.21	-2.06	.03

Table A6. Effects of bilingual language background on norm judgments in the Surgeon dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived permissibility of moral violation for the Surgeon dilemma. SE = standard error.*

Effects	b	SE	t	p value
Proficiency	-0.26	0.19	-1.37	.16
AoA	-0.04	0.19	-0.22	.82
Dominance	-0.13	0.19	-0.68	.49

Table A7. Effects of bilingual language background on norm judgments in the Factory dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived permissibility of moral violation for the Factory dilemma. SE = standard error.*

Effects	b	SE	t	p value
Proficiency	-0.08	0.20	-0.42	.66
AoA	0.13	0.19	0.69	.48
Dominance	0.10	0.21	0.50	.61
Proficiency X AoA	-0.47	0.22	-2.07	.03
Proficiency X Dominance	-0.30	0.15	-1.95	.05

Table A8. Effects of bilingual language background on norm judgments in the Bike week dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived permissibility of moral violation for the Bike week dilemma. SE = standard error.*

Effects	b	SE	t	p value
Intercept	4.41	0.15	27.58	<.001
Proficiency	0.26	0.18	1.45	.15
AoA	-0.29	0.16	-1.80	.07
Dominance	-0.24	0.18	-1.33	.18

Table A9. Effects of bilingual language background on emotionality in the Surgeon dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived emotional distress for the Surgeon dilemma. SE = standard error.*

Effects	b	SE	t	p value
Intercept	4.77	0.16	29.72	<.001
Proficiency	0.46	0.17	2.56	.01
AoA	-0.47	0.16	-2.80	.006

Dominance	-0.21	0.18	-1.15	.25
AoA X Dominance	0.44	0.15	2.77	.006

Table A10. Effects of bilingual language background on emotionality in the Factory dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived emotional distress for the Factory dilemma. SE = standard error.*

Effects	b	SE	t	p value
Intercept	4.52	0.17	26.41	<.001
AoA	-0.52	0.17	-2.94	.004
Dominance	-0.04	0.17	-0.27	.78
AoA X Dominance	0.46	0.16	2.75	.007

Table A11. Effects of bilingual language background on emotionality in the Bike week dilemma (Experiment 4). *Parameters of the final model for the analyses of the perceived emotional distress for the Bike week dilemma. SE = standard error.*

Effect	b	SE	z	p value
Intercept	-0.802	0.417	-1.922	0.055
L2 objective proficiency [a]	0.121	0.159	0.762	0.446
L2 normalized exposure	1.912	1.899	1.007	0.314
L2 immersion [a]	-5.157	5.139	-1.003	0.316
L2 objective proficiency [a] * FL normalized exposure	-0.865	0.846	-1.022	0.307
L2 objective proficiency [a] * L2 immersion [a]	3.138	3.158	0.994	0.320

L2 normalized exposure * L2 immersion [a]	26.635	27.393	0.972	0.331
L2 objective proficiency [a] * L2 normalized exposure * L2 immersion [a]	-22.900	20.152	-1.136	0.256

Table A12. Effects of bilingual language background on moral decisions in the uncertain version of the Bike week dilemma (Experiment 5). *Parameters of the final model for the analyses of moral choices (i.e., number of utilitarian responses) for the Bike week dilemma (UC). SE = standard error. [a] The variable was scaled.*

Effects	b	SE	z	p value
Intercept	-0.961	0.312	-3.081	0.002
L2 objective proficiency [a]	0.062	0.095	0.659	0.510
L2 normalized exposure	2.046	1.327	1.542	0.123
L2 immersion [a]	-0.950	3.911	-0.243	0.808
L2 objective proficiency [a] * L2 normalized exposure	-0.587	0.440	-1.333	0.183
L2 objective proficiency [a] * L2 immersion [a]	1.939	1.404	1.381	0.167
L2 normalized exposure * L2 immersion [a]	2.708	15.645	0.173	0.863
L2 objective proficiency [a] * L2 normalized exposure * L2 immersion [a]	-10.418	6.246	-1.668	0.095

Table A13. Effects of bilingual language background on moral decisions in the Bike week dilemmas (Experiment 5). *Parameters of the final model for the analyses of moral choices (i.e., number of utilitarian responses) for the Bike week dilemma. SE = standard error. [a] The variable was scaled.*

Effects	b	SE	t	p value
Intercept	4.876	0.275	17.764	< 0.0001
L2 objective proficiency [a]	0.023	0.076	0.306	0.760
L2 normalized exposure	-1.962	1.053	-1.864	0.067
L2 immersion [a]	2.630	3.305	0.796	0.429
L2 objective proficiency [a] * L2 normalized exposure	-0.270	0.259	-1.043	0.301
L2 objective proficiency [a] * L2 immersion [a]	1.470	0.912	1.613	0.112
L2 normalized exposure * L2 immersion [a]	-3.868	11.076	-0.349	0.728
L2 objective proficiency [a] * L2 normalized exposure * L2 immersion [a]	-3.775	2.007	-1.881	0.065

Table A14. Effects of bilingual language background on emotionality in the uncertain version of the Surgeon dilemma (Experiment 5). *Parameters of the final model for the analyses of perceived emotional distress for the Surgeon dilemma (UC). Note. SE = standard error. [a] The variable was scaled.*

Effects	b	SE	z	p value
Intercept	-0.817	0.186	-4.386	< 0.0001

L2 objective proficiency [a]	0.015	0.046	0.318	0.751
L2 immersion [a]	-2.167	2.261	-0.958	0.338
L2 immersion [a] * L2 objective proficiency [a]	1.356	0.631	2.149	0.032

Table A15. Effects of bilingual language background on explorative choices in the Broken Glass problem (Experiment 5). *Parameters of the final model for the analyses of choices (i.e., number of explorative responses) for the Broken Glass problem. SE = standard error. [a] The variable was scaled.*

Effects	b	SE	z	p value
Intercept	-0.755	0.452	-1.668	0.095
L2 objective proficiency [a]	0.110	0.183	0.602	0.547
L2 normalized exposure	1.802	2.051	0.879	0.380
L2 immersion [a]	-0.664	6.321	-0.105	0.916
CRT-Reflective score [a]	-0.243	0.279	-0.871	0.384
L2 objective proficiency [a] * L2 normalized exposure	-0.732	0.986	-0.742	0.458
L2 objective proficiency [a] * L2 immersion [a]	4.813	3.787	1.271	0.204
L2 normalized exposure * L2 immersion [a]	40.488	34.297	1.180	0.238
L2 objective proficiency [a] * CRT-Reflective score [a]	-0.040	0.080	-0.497	0.619

L2 immersion [a] * CRT-Reflective score [a]	-0.817	4.482	-0.182	0.855
L2 objective proficiency [a] * L2 normalized exposure * L2 immersion [a]	-38.001	27.038	-1.405	0.160
L2 objective proficiency [a] * L2 immersion [a] * CRT-Reflective score [a]	-3.834	1.539	-2.492	0.013

Table A16. Effects of bilingual language background and reflective thinking on moral decisions in the uncertain version of the Bike week dilemma (Experiment 5). *Parameters of the final model including CRT-Reflective as a further predictor for the analyses of moral choices (i.e., number of utilitarian responses) in the Bike-week dilemma (UC). SE = standard error. [a] The variable was scaled.*

Effects	b	SE	z	p value
Intercept	-2.875	0.770	-3.731	0.0002
L2 normalized exposure	1.015	3.068	0.331	0.741
CRT-Reflective score [a]	-1.239	0.726	-1.708	0.088
L2 normalized exposure * CRT-Reflective score [a]	6.236	3.353	1.860	0.063

Table A17. Effects of bilingual language background and reflective thinking on moral decisions in the uncertain version of the Surgeon dilemma (Experiment 5). *Parameters of the final model including CRT-Reflective as a further predictor for the analyses of moral choices (i.e., number of utilitarian responses) in the Surgeon dilemma (UC). SE = standard error. [a] The variable was scaled.*

Effects	b	SE	t	p value
Intercept	4.730	0.263	17.983	< 0.0001

L2 objective proficiency [a]	0.073	0.073	1.006	0.319
L2 normalized exposure	-0.690	1.082	-0.638	0.526
Risk-taking score [a]	0.009	0.037	0.243	0.809
L2 objective proficiency [a] * L2 normalized exposure	-0.623	0.275	-2.263	0.027
L2 objective proficiency [a] * Risk-taking score [a]	0.012	0.009	1.284	0.204
L2 normalized exposure * Risk-taking score [a]	-0.123	0.120	-1.025	0.309
L2 objective proficiency [a] * L2 normalized exposure * Risk-taking score [a]	-0.090	0.037	-2.426	0.018

Table A18. Effects of bilingual language background and risk-taking attitude on emotionality in the uncertain version of the Surgeon dilemma (Experiment 5). *Parameters of the final model including risk-taking attitude as a further predictor for the analyses of perceived emotional distress in the Surgeon dilemma (UC). SE = standard error. [a] The variable was scaled.*

Effects	b	SE	z	p value
Intercept	-0.904	0.198	-4.566	< 0.0001
L2 objective proficiency [a]	0.022	0.047	0.457	0.647
L2 immersion [a]	-2.516	2.375	-1.059	0.290
Risk-taking score [a]	0.062	0.026	2.396	0.017
L2 objective proficiency [a]	1.337	0.655	2.042	0.041

* L2 immersion [a]				
L2 immersion [a] * Risk-taking score [a]	0.644	0.331	1.947	0.052

Table A19. Effects of bilingual language background and risk-taking attitude on explorative choices in the Broken Glass problem (Experiment 5). *Parameters of the final model including risk-taking attitude as a further predictor for the analyses of explorative choices in the Broken Glass problem. SE = standard error. [a] The variable was scaled.*

Movie clip	Emotion Category
Breaking Bad	Fun
Breaking Bad 1x5	Neutral
Buffy 5x16	Sad
Desperate Housewives 3x18	Fun
Desperate Housewives 8x17	Sad
Due Date	Fun
Firefly Lane	Neutral
Forrest Gump	Sad
Fracture	Neutral
Gilmore Girls	Neutral
Green Mile	Sad
I now pronounce you Chuck and Larry	Fun
Interstellar	Sad
Interstellar	Sad
Little Fockers	Fun
Me Before You	Sad
Meet the Parents	Fun
My sister's keeper	Sad
Notting Hill	Neutral
Precious	Sad
Spotlight	Neutral
State of Play	Neutral
Stepmom	Sad
The 40-Year-Old Virgin	Fun
The 40-Year-Old Virgin	Fun
The Game	Neu
The Notebook	Sad
The Office 1x2	Fun
The Office 4x13	Fun
This is Us 1x16	Sad
This is Us 1x9	Neutral
This is Us 2x18	Neutral
This is Us 4x7	Neutral
Vacation	Fun
Yes Man	Fun
Yes Man	Fun

Table A20. Experimental stimuli (Experiment 3). *The table represents the title of the movie or TV series from which the clips were extracted (on the left) and the respective emotional category (on the right).*