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KINEMATIC CHARACTERIZATION OF SPONTANEOUS AND POSED EMOTIONAL FACIAL EXPRESSIONS

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Abstract

Emotions are one of the building blocks of human life. However, how humans dynamically and genuinely express their emotions on the face is still little studied.

In the past decade, numerous papers have criticized classical methods of investigation, calling for a more sophisticated approach that can analyse how humans dynamically manifest 3-D facial expressions along spatial, speed and temporal dimensions. Another major limitation of the current literature is that almost all studies to date have typically used static images of posed expressions. However, small changes in the dynamic development of a facial expression can characterize and distinguish authentic and posed facial expressions, an under-investigated topic that invalidates the data collected so far. Last remark: although the adoption of dynamic stimuli is gaining momentum recently, the induction method adopted to elicit facial expressions is heterogeneous, leading to contradictory results in the literature. Not to mention self-assessment questionnaires of felt emotions, which are often still anchored on single, mutually exclusive basic emotions that do not consider the nuances present in real emotions.

In conclusion, the lack of objective tools to investigate dynamic features of expression and inconsistencies in the stimuli and induction methods adopted are all sources of poor consensus on the syntax and morphometry of facial expressions of emotion.

It is time to revise the science of emotion with tools such as three-dimensional kinematics in combination with Facial Action Coding System (FACS), valid experimental designs that adopt dynamic stimuli, more effective induction methods, and self-assessment questionnaires that can measure the various principal and secondary components that make up an emotion.

In this doctoral thesis, I manipulated both the type of expressions performed (posed or spontaneous) and the method of induction (Emotional or Motor Contagion) using static and dynamic stimuli. In a first set of experiments (see Part 2, Experiment 1 for each chapter), I presented participants with: (i) videoclips extracted from movies - aimed at eliciting spontaneous expressions of emotions (i.e., Emotional Contagion), and (ii) static 2-D images of expressions to make them perform posed expressions (i.e., Voluntary Mimicry). In a second set of experiments (Experiment 2 for each chapter), spontaneous expressions were elicited by videos showing people expressing their emotion in a direct, frontal manner (i.e., Motor Contagion) while posed expressions were induced

by the same procedure as in the first set of experiments (i.e., Voluntary Mimicry). The results showed that spontaneous and posed expressions of the same emotions are in fact characterised and distinguished by a number of spatial, speed and temporal parameters of movement (Part 2). As concern the methods of induction, Motor Contagion activates all kinematic components of space, speed and time to a greater degree than Emotional Contagion and is particularly effective in inducing posed expressions, while Emotional Contagion is better at triggering spontaneous reactions. Moreover, the results showed that the emotions experienced are not unique, prototypical and mutually exclusive, but are composed by several shades of different emotions, as revealed by my new Continuous Emotion Rating (CER) paradigm, which allows to highlight the relative contributions of each emotion (Part 3).

In my doctoral dissertation, I identified entirely new methods for the study of emotional expressions, that will lead to a theoretical and methodological shift in the study of emotions. I believe that the most useful solution to address the complex world of emotion expression is to define a new approach that integrates traditional with more innovative methods, and new tools for self-detection of multifaceted emotional experiences that will have spill overs to various fields such as artificial intelligence and robotics.

PART 1

THEORETICAL BACKGROUND

1 | The expression of emotions

Humans are capable of creating more than 10.000 combinations of facial expressions. Even the smallest movement of our face can reveal our thoughts, intentions and feelings (Jack & Schyns, 2015), making the human face one of the most powerful communicative tools our species has (Rinn, 1984).

Human face is never static, but it continuously acts and reacts with the coordinated action of the facial muscles (Calvo et al., 2018). Dynamic changes in the facial expression of emotions are a particularly valuable source of information: they indicate changes in the emotional state of individuals. Our understanding of such dynamic information and the corresponding dynamic expression databases, however, are so far very limited (for a review, see Krumhuber et al., 2017).

Basic facial expressions

The display of emotional expressions plays an important role in social perception and in social interactions. Psychologist Paul Ekman dedicated most of his career to the study of facial expressions. He has argued that at least six emotions are basic and universal, each of which is characterized by a specific combination of facial actions resulting from the contraction of underlying facial muscles: happiness, sadness, fear, anger, surprise, and disgust (i.e., the basic six; Ekman et al., 1969; Ekman & Friesen, 1971). Over the last century, the science of emotion gradually anchored to these facial expressions: they were described as unitary entities and conceived as if they were mutually exclusive categories. In particular, basic-emotion theory proposes that a limited number of emotions are manifested through organized and recurrent patterns of behavior in a kind of "one-to-one" correspondence, conserved by evolution to handle basic life situations (Damasio & Carvalho, 2013; Ekman, 1992a, 1992b, 2003; Ekman & Cordaro, 2011; LeDoux, 1995, 2012). Jack and colleagues (2016) further narrowed this view by suggesting a four-scheme model of expression, each of which communicates a specific combination of valence, arousal and dominance, probably evolved from a simpler communication system (Gu et al., 2019). Needless to say, all these elegant models leave most human expressions unexplored (Adolphs et al., 2019; Barrett, 2017; Barrett et al., 2019). Moreover, the term basic seems to underlie that the emotions are discrete, rather than a family of related states (Bänziger et al., 2012; Cordaro et al., 2018; Keltner & Cordaro, 2017; Roseman, 2011; Scherer & Ellgring, 2007; Tracy & Matsumoto, 2008). Instead of considering happiness as a single emotion, for instance, research should try to unpack emotional categories into their components: the happiness umbrella might cover joy, pleasure, compassion, pride, and so on. According to the Constructionist theory, a wide range of emotions have evolved, shaped by language and cognitive appraisal (Russell & Barrett, 1999). All the emotions can be located in a circle called circumplex (Russell, 1980), characterized by different amounts of valence (pleasure/displeasure axis) and arousal (high/low axis). Basic-emotion and Constructionist theories have been pitted against each other for more than a century in the so-called 100-year war (Lindquist et al., 2013). Now, thanks to modern neuroscience, we are finally beginning to understand the complexity of the emotional world. Emotional expression might be far richer and more complex than the prototypical patterns of facial muscle movements so far considered.

2 | Facial blends of emotion:

The hemispheric lateralization puzzle

Many — even most — experiences of emotion are complex blends of emotion (Du et al., 2014; Parr et al., 2005). Multiple emotions can occur in a rapid sequence, again and again, or can merge in a mosaic. Humans have the capacity to produce facial blends of emotions in which the upper and lower face simultaneously display different expressions, suggesting that their underlying emotions are compound entities (Larsen et al., 2001; Scherer, 2009). Notably, there are exemplars (e.g., surprise-frown or smile-grimace) in which the expression on the Right and Left sides of the face differs, thus providing evidence that facial blends of emotions may also occur across the vertical facial axis (i.e., Left-Right areas). In this vein, three major models of emotional processing address the so-called "hemispheric lateralization of emotions" topic in humans (Demaree et al., 2005; Killgore & Yurgelun-Todd, 2007). The Right Hemisphere Hypothesis asserts that all emotions and their associated expressions are a dominant and lateralized function of the right hemisphere. The Valence Hypothesis states that negative, avoidance or withdrawal-type emotions and their associated expressions are lateralized to the right hemisphere, whereas positive approach-type emotions and their associated expressions are lateralized to the Left hemisphere. Finally, the Emotion-type Hypothesis (Ross et al., 2007, 2016) affirms that primary emotional responses are initiated by the right hemisphere on the left side of the face, whereas social emotional responses are initiated by the left hemisphere on the right side of the face. The most striking examples are expressions that display a "double peak" phenomenon (e.g., grimace-smile characterized by an initial movement followed by a slight relaxation and then a second movement to the final peak) as a result of dual or competing hemispheric motor control (Ross et al., 2016). In some instances, the initial movement starts on one side of the face and the second movement starts on the opposite side of the face. For instance, Duchenne and non-Duchenne are terms used to classify if a smile reflects a true emotional feeling versus a false smile (Ekman et al., 1988; Ekman & Friesen, 1982). A felt (Duchenne) smile is very expressive and it is classically described as causing the cheeks to lift, the eyes to narrow and wrinkling of the skin to produce crow's feet. A false (non-Duchenne) smile, instead, would only involve the lower face area. However, recent research has shown that the difference between a felt (Duchenne) versus a fake smile might in fact be revealed by the side of the face initiating the smile (Ross et al., 2016).

Despite the importance of emotion in human functioning, scientists have been unable to reach a consensus on the debated issue concerning the lateralization of emotions. We believe that investigating the time course of facial blends of emotions, which can be controlled consciously only in part, would provide a useful operational test for comparing the different predictions of various models, thus allowing this long-standing conundrum to be solved.

FACIAL INNERVATION

Striated muscles beneath the skin of the face are innervated by the seventh cranial nerve. The contraction of these muscles creates folds, lines, and wrinkles in the facial skin and the movement of landmarks such as the Eyebrows and corners of the mouth (i.e., Cheilion).

Facial expressions are organized predominantly across the horizontal facial axis (i.e., upper-lower areas). Notably, the upper face muscles (eye areas) are mainly controlled by the subcortical and extrapyramidal systems, whereas the lower face (mouth area) is under the voluntary control of the motor system (Gazzaniga & Smylie, 1990; Hopf et al., 1992; Krippl et al., 2015; Ross et al., 2007). Hence, only the muscles of the lower part of the face are transversely innervated from the contralateral side (Morecraft et al., 2004; Ross et al., 2016) (Figure 2.1). Small changes in the lateralization of a facial expression can thus characterize voluntarily controlled facial expressions (i.e., posed displays), a topic that has yet to be investigated.

Voluntary Pathway

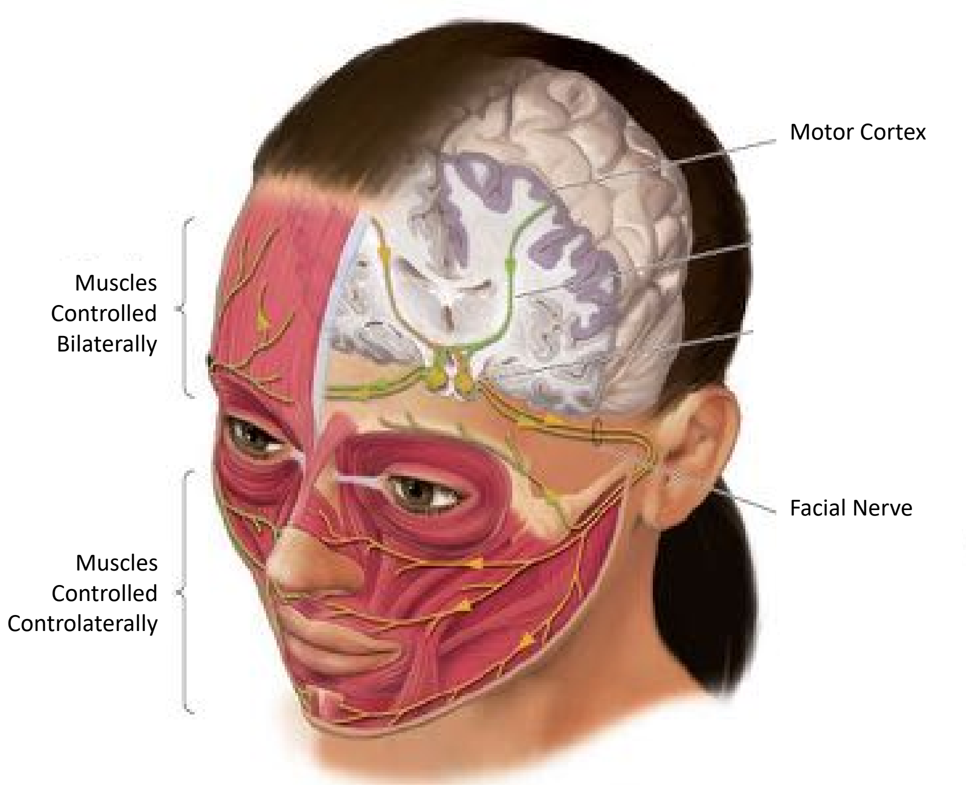

Figure 2.1. The Voluntary Pathway. The muscles of the upper part of the face are innervated from both hemispheres, while the muscles of the lower part of the face are innervated transversely from the contralateral side. Image adapted from Freberg (2018).

Posed and spontaneous expression of emotions

For each emotion there is a broad family of possible expressions involving different facial muscles at different times and with different intensities (Ekman, 2009). This variability is due to people's ability to voluntarily or spontaneously modulate their emotional expressions (Ekman & Friesen, 2003; Etcoff et al., 2021; Reed & DeScioli, 2017; Zloteanu et al., 2021) which, in turn, depends on the existence of two anatomically separate pathways for the production of facial expressions: the Voluntary Pathway (VP) and the Involuntary Pathway (IP). Thus, we have different pathways for posed (i.e., voluntarily controlled) and spontaneous (i.e., involuntarily produced) facial displays (Ross et al., 2016).

Posed facial expressions are displayed intentionally by a person who pretends to transmit a specific emotion (Namba et al., 2017), while spontaneous facial expressions are elicited by true emotional content and usually correspond to a more genuine emotional experience (Niedenthal et al., 2010; Zloteanu & Krumhuber, 2021). For example, a smile is genuine when listening to a joke. However, people also try to smile when they feel angry, scared, tired or embarrassed, to hide these emotions in contexts where they are inappropriate. Notably, the upper face muscles (i.e., eye areas) are mainly controlled by the subcortical and extrapyramidal systems, whereas the lower face (i.e., mouth area) is under the voluntary control of the motor system (Gazzaniga & Smylie, 1990; Hopf et al., 1992; Krippl et al., 2015; Ross et al., 2007). This means that the muscles of the upper face are innervated bilaterally, and they are less likely to be impaired than the muscles in the lower face, which are cross-innervated prevalently from the contralateral side (Morecraft et al., 2004). When a person suffers damage to the motor cortex of one hemisphere, for instance, there is relatively little impact on the muscle tone of the upper face, which continues to receive ipsilateral input from the healthy hemisphere. However, the contralateral lower face will be paralyzed (Rinn, 1984). An interesting implication is that we have distinct and independent pathways for posed and genuine facial expressions (Ross et al., 2016). In particular, the genuine pathway has been associated with more synchronized, smooth, and symmetrical expressions compared to the pyramidal voluntary system (Ross et al., 2019). Moreover, when a genuine emotion is experienced, the expression of this emotion cannot be totally inhibited or modified, and it follows a rather stereotyped pattern (Baker et al., 2016). For example, a genuine smile – like automatic movements - can appear as fast as 0.30 seconds, and it usually fades away after 3 to 4 seconds (Schmidt et al., 2003). However, the diversity of appearance and dynamics of spontaneous smiles still requires a better understanding of a smile's properties and patterns, to determine what features or temporal parameters are key in transmitting information and how they variate in different contexts (Schmidt et al., 2003). What is needed to make sense of emotional expressions is therefore a much richer taxonomy.

State of the art: what is missing in the study of emotion expression?

In the classical literature, there is no convincing evidence that persons subjected to 'basic emotions' proposed by the Affect Programme Theory (APT) of facial expression (i.e., happiness, surprise, disgust, sadness, anger, and fear; Ekman, 1970, 1992a) typically display the facial expressions predicted by the theory. The available evidence suggests that these emotions are not typically accompanied by their APT expressions: the inter- and intra-individual correlations between self-reports and facial activations are in fact low to modest (Reisenzein et al., 2013).

The current literature is thus characterized by an open question: Is the lack of reliable data on emotion expressions a methodological problem caused by the adoption of: i) ineffective instruments? ii) static visual stimuli? iii) poor induction methods? iv) insensitive self-report questionnaires? Or all four?

This thesis aims to give an unambiguous answer to these questions and individuate the missing pieces. To this end, I will: i) make use of three-dimensional facial analysis with a 6-camera infrared optoelectronic system, ii) adopt dynamic stimuli and iii) effective induction methods, and iv) create a new multi-dimensional self-report to allow full description of one's emotional state.

3-D Analysis methods

The word 'emotion' comes from the Latin word 'emovere', meaning 'to set in motion'. It was brilliantly coined in the early 1800s by British philosopher Thomas Brown (1778-1820). Two centuries since Brown's death, the motor component of emotion is still poorly investigated. To date, current analysis methods only capture a fraction of the broad motor variability in human emotional responses: an aspect that has been largely neglected is the key role of temporal dynamics as a locus for investigating the encoding of emotional displays.

Past research systematically analysed muscle activation through the Facial Action Coding System (FACS; Ekman & Friesen, 1978; Ekman et al., 2002). A FACS coder decomposes an observed expression into a fixed number of specific Action Units (AUs; i.e., contraction or relaxation of distinct facial muscles). This approach, despite being widely used, has a few drawbacks: i) it analyses each facial movement independently from each other, while many facial muscles are closely related to each other and cannot move independently (Hao et al., 2018); ii) it is affected by conflicting definitions of dynamic parameters during feature extraction, causing inconsistencies in the literature (Guo et al., 2018); iii) it requires a lot of training, and iv) it is very time-consuming. A trained FACS operator can take hours to code one minute of video data depending on the complexity and density of facial expressions. To solve this last issue researchers created automatized algorithms (Chu et al., 2017; Martinez, 2017), which work very well in laboratory, when images can be controlled. However, their accuracy drops substantially when they detect more ecologic facial expression (Benitez-Quiroz et al., 2017). At the moment, their accuracy and reliability need to be enhanced and further verified (Baltrusaitis et al., 2018; Cardaioli et al., 2022; Guo et al., 2018). Only recently, researchers started focusing on more dynamic features such as the total duration, the onset and offset, the amplitude, and the asymmetry of facial expressions with open-source software and automated 2-D facial movement analysis (Guo et al., 2018; Krumhuber & Kappas, 2005; Schmidt et al., 2006, 2009). However, none of these approaches has yet analysed the unfolding of a facial expression with a high-definition optoelectronic system equipped with 6 infrared cameras - in conjunction with the concurrent validation of a professional FACS coder, to expand our understanding of how facial displays unfold over time and space. This method is in fact remarkably accurate in the quantitative capture of facial motion, outperforming the canonical 2-D computer vision system (Ancillao et al., 2016; Linstrom, 2002; Vimercati et al., 2012). In this Ph.D. thesis I defined a unique set of universal and easily recognizable reference points for the face to create a 3-D Navigation System. I then applied a unique set of markers (i.e., reflective semi-spheres) on the defined landmarks to allow the detailed 3-D analysis of all motion features. Key kinematic parameters were then computed for the characterization of movements: total duration of each movement, peak Distances, Times, Velocities, Accelerations and Decelerations.

Dynamic and spontaneous stimuli

A huge bias in the psychological literature of emotions consists in the widespread use of posed and static stimuli (Biehl et al., 1997; Ekman & Friesen, 1976; Motley & Camden, 1988; Russell, 1994; Tcherkassof et al., 2007; Wallbott & Scherer, 1986). Only recently, some dataset including spontaneous emotions have been released (Guerdelli et al., 2022; Maffei & Angrilli, 2019; Miolla et al., 2022). The majority of emotional facial data sets of stimuli used in scientific research are thus based on static photographs of non-spontaneous facial expressions (O'Reilly et al., 2016; Tcherkassof et al., 2013). This methodology has been questioned given the low generalizability of its results (Russell, 1994; Tcherkassof et al., 2013). People project their stereotypes in posed expressions, their common view of what they believe an emotional facial expression should look like (e.g., a scowling facial configuration to express anger), but these displays do not necessarily correspond to how people actually behave in real life (Barrett et al., 2019). Genuine expressions differ specifically from posed expressions in both temporal and morphological features (Cohn & Schmidt, 2003; Ekman & Rosenberg, 2005; Sato & Yoshikawa, 2004; Valstar & Pantic, 2010; Wehrle et al., 2000; Yoshikawa & Sato, 2006). In first instance, genuine facial expressions can occur within a fraction of a second (i.e., micro expressions; Ekman, 2009). In second instance, they are usually less intense and finer than posed expressions classically used in laboratory (Tcherkassof et al., 2013). This disparity could explain why the recognition accuracy of posed emotions, characterized by prototypical and very intense facial configurations, is much higher than that of spontaneous emotions (Barrett et al., 2019). Thus, more genuine stimuli are needed in research. Unfortunately, such databases are still rare because of the practical (e.g., the methodology needed to collect these stimuli) and ethical difficulties (see Philippot, 1993 for initial considerations) of documenting and collecting genuine expressions (Tcherkassof et al., 2013). A related problem in the study of emotions expressions is that the majority of the literature have employed static facial stimuli (Dawel et al., 2015; Douglas et al., 2012; Li et al., 2012; McLellan et al., 2010, 2012; Tcherkassof et al., 2007). Only the peak intensity of emotions was usually shown, while the time-course of facial expressions was substantially ignored. However, facial expressions are not an all-or-nothing phenomenon: the nature of facial expressions is that they are dynamic in presentation (Rymarczyk et al., 2019). Recent literature suggests that dynamic displays enhance the ability not only to correctly recognize facial expressions (Ceccarini & Caudek, 2013; Cunningham & Wallraven, 2009; Krumhuber et al., 2013), but also to discriminate genuine and posed facial expressions of emotion (Krumhuber et al., 2013; Lander & Butcher, 2020; Namba et al., 2018, 2021) and to elicit stronger muscle activation during mimicry (Rymarczyk et al., 2016). The use of dynamic emotional stimuli is more ecologically valid (Bernstein & Yovel, 2015), as an emotional message is usually reflected in dynamic complex action patterns and not in static facial clues (O'Reilly et al., 2016; Tcherkassof et al., 2013). This is probably because dynamic faces can transmit an evolving hierarchy of signals over time (Delis et al., 2016), thus providing much more information than static pictures (e.g., time course, change of speed, facial-feature amplitude, and irregularity of an expression; Tcherkassof et al., 2013). This effect has also been confirmed by the activation of a broader neural network in the observer when using dynamic stimuli compared to static emotion stimuli (Ambadar et al., 2005; Trautmann et al., 2009; Weyers et al., 2006). Only recently, an increasing number of dynamic emotion data sets have been developed, including, for instance, the Cohn–Kanade AU-Coded Facial Expression Database (Kanade et al., 2000; Lucey et al., 2010) and the Video Database of Moving Faces & People (O'Toole et al., 2005). However, an aspect that has been largely neglected is the key role of temporal dynamics as a locus for investigating the encoding of facial displays. To date, little is known about the temporal course of facial expressions (Tcherkassof et al., 2013). Temporal parameters, such as the apex period (i.e., the time duration before the peak intensity starts decreasing) and movement time (i.e., the time from facial display onset until it disappears) of facial expressions, might allow unveiling the secret syntax of emotional language. For instance, recent research has shown that eyelid movements precede eyebrow movements in genuine surprise displays (Namba et al., 2017) and this could help to differentiate spontaneous from simulated expressions. In the case of smiles, shorter durations and more irregular onset have been associated with lower perceived genuineness (Krumhuber et al., 2013).

To my knowledge, only a dataset is available including both dynamic and genuine emotions, thus overcoming the two limitations described in the previous paragraphs: the Padova Emotional Dataset of Facial Expressions (PEDFE), a validated dataset including both dynamic and static stimuli depicting genuine (n=707) and posed (n = 751) facial emotional expressions from 56 actors (Miolla et al., 2022).

To sum up, research on emotion expression has been extensively conducted during passive observation of posed static pictures (e.g., Karolinska Directed Emotional Faces; Lundqvist et al., 1998). However, ecological and dynamic stimuli such as spontaneous recordings from real-time interactions have rarely been adopted. Crucially, posed expressions have lower ecological validity and differ in timing from spontaneous ones (Ekman & Rosenberg, 2005). Approaches based on static and simulated portrayals may, therefore, fail to generalize to real-world behavior (Zeng et al., 2009). Even distinguishing facial expressions into genuine or posed, depending on the manner and context in which they are produced, may be too simplistic, because they are really just the poles of a broad spectrum with various gradations of colour.

INDUCTION METHODS: EMOTIONAL CONTAGION AND MOTOR CONTAGION

Emotional contagion refers to the reproduction of an emotional state in an observer—for instance, through an automatic mimicking (unintentional imitation) of somato-visceral responses including facial expressions, vocalizations, and postures (Cacioppo et al., 2000). Mimicry can be both consciously controlled (i.e., motor mimicry controlled by the motor muscles) or it can be controlled by the autonomic nervous system (e.g., heart rate synchronization, blushing; Prochazkova & Kret, 2017). Investigations using facial electromyography have reliably shown that observers often show motor mimicry to the emotional expressions they see (Cacioppo et al., 1990; Cacioppo & Petty, 1981).

Many emotion-elicitation techniques have been used in previous studies, like exposure to emotional slides, music, pictures, autobiographical recollection, mental imagery, facial or respiratory feedback, real-life techniques, etc. (Schaefer et al., 2010; Sowden et al., 2021). However, videos are nowadays the most widely used stimuli to study the relationship between facial expressions and emotions. They present several advantages in the laboratory setting: they are simple to apply, they can elicit strong subjective and physiological changes, and their dynamic nature provides a good artificial model of reality, without the ethical and practical problems of other methods (Gross & Levenson, 1995; Schaefer et al., 2010). A great source of confusion in the literature, although, is that even when dynamic video clips were used, the adopted induction method (Siedlecka & Denson, 2019) was heterogeneous. This method in fact, can make use of various stimuli: for example, in the case of happiness, observation of: i) hilarious scenes that make people smile (i.e., Emotional Contagion, the transmission of emotions from one individual to another; Kavanagh & Winkielman, 2016; Prochazkova & Kret, 2017) or instead ii) people expressing their emotion in a direct, frontal manner that promotes Motor Contagion (i.e., the automatic reproduction of the motor patterns of another individual, one of the portals that allows Emotional Contagion; Hess & Fischer, 2014). Motor Contagion, in turn, is based on Visuomotor priming - defined as the facilitation to perform an action congruent with the just-observed one (Heyes, 2011).

Each strategy clearly differs from the other in terms of spontaneity and likely activates different Pathways. To clarify, Voluntary Mimicry specifically involves the VP and is sub-served by the mirror system, a neural circuit activated both by the execution of actions and by simple observation of the same actions performed by others (Rizzolatti et al., 2001). Emotional Contagion, instead, is sub served by the IP. The adoption of different elicitation methods, in turn, produces different facial movement patterns, which results in inconclusive and contradictory results in the literature (Namba et al., 2017; Zloteanu et al., 2021).

Do Voluntary Mimicry, Emotional and Motor Contagion involve overlapping or distinct mechanisms?

Voluntary mimicry of emotion by definition requires voluntary control of expression, which passes through the VP. In the case of emotional contagion, on the other hand, induced expression is mediated by IP, that is, the pathway mediated by subcortical circuits, which passes through the basal ganglia and is not under voluntary control. What about Motor Contagion, what mechanism does it involve? Either or both? With the help of high-definition kinematics, I will try to answer this experimental question.

Another interesting question that emerges from this examination and may have great consequences in future developments in research on facial expressions of emotion is: What is the most effective method of induction? To answer this question, I will correlate the kinematics data with a questionnaire designed to assess empathy (i.e., the capacity to understand or feel what another person is experiencing). The Interpersonal Reactivity Index (IRI) is among the oldest published measurement tools that provides a multi-dimensional assessment of empathy (Davis, 1983). It comprises a self-report questionnaire of 28 items, divided into four 7-item scales covering the subdivisions of affective and cognitive empathy described below. Empathy has two major components (Shamay-Tsoory et al., 2009):

1) Affective empathy, also called emotional empathy, is the ability to respond with an appropriate emotion to another's mental states and is based on Emotional Contagion. Affective empathy, in turn, can be subdivided into the following scales: i) Empathic concern (i.e., sympathy and compassion for others in response to their suffering, and ii) Personal distress (i.e., feelings of discomfort and anxiety in response to another's suffering).

2) Cognitive empathy corresponds to the ability to understand one’s emotional state from their perspective. Cognitive empathy can be subdivided into the following scales: i) Perspective-taking: the tendency to spontaneously adopt others' psychological perspectives, and ii) Fantasy: the tendency to identify with fictional characters.

Notably, emotional empathy entails an emotional response that is similar to what the other person is expressing, thereby aligning the emotional states between these individuals. Cognitive empathy, instead, corresponds to the ability to understand one's emotional state from their perspective.

Multi-dimensional self-reports

Introspective measures constitute an essential validation approach (Gray & Watson, 2007). However, another critical issue in the recent literature are the emotional self-reports completed by participants after viewing emotional stimuli. The forced-choice paradigm with mutually exclusive terms classically adopted in the literature lacks ecological validity. An essential improvement in the literature would be obtained by adopting free-response tasks, where participants would be allowed to spontaneously describe their emotions without any restriction. On the other hand, there is no widely accepted method for scoring freely provided responses. Ideally, self-report description should be easy for participants to fulfil and for scientists to score. To solve this methodological problem, I devised a new Continuous Emotional Rating (CER) task: after observing an emotional videoclip, participants were given a reference grid with the list of six basic emotions, and they had to assign a percentage to each label in order to fully characterize their felt emotion: for example, "I feel scared eight (on a scale of one to nine), surprised three (one to nine), sad 4 (one to 9), and zero all the others". Notably, this multiple rating task made it possible to describe with great accuracy both the participants' blends of emotions, and their relative intensity.

THE PRESENT RESEARCH

As the research reported in this Ph.D. thesis was inspired by Ekman's Affect Programme Theory, I will discuss the empirical evidence separately for each emotion from the core of 'basic emotions' proposed by this theory: happiness, surprise, disgust, sadness, anger, and fear.

The main purpose of the present study was to thoroughly investigate the performance of *spontaneous* and *posed* expressions of the six basic emotions with a mathematical approach by studying the spatiotemporal characteristics of kinematics (i.e., distances, time, and speed) and correlating these results with an index of empathic behavior (i.e., the IRI questionnaire). The second objective was to manipulate the *induction method* to test its impact on the expression of spontaneous and posed facial displays. The third goal was to investigate the multi-coloured compositions of principal and secondary emotions (i.e., *mixed emotions*).

Data collection was divided into three main parts: the first one was aimed at testing if each facial expression differs across the horizontal axis (i.e., mouth vs eyebrows) and the vertical axis (i.e., Left vs Right side of the face) for spontaneous and posed expressions after watching videoclips from comedy movies (i.e., Emotional Contagion; see Experiment 1 in every chapter); the second part was aimed at exploring the effect of adopting as induction method the Motor Contagion (see Experiment 2 in every chapter). The third part was aimed at highlighting the coexistence of multiple emotions with different relative contributions through a new paradigm in which participants had to score their feelings after viewing a video ("How do you feel?") on different Likert scales, one for each of the six basic emotions (see Part 3).

In all the Experiments 1 of the thesis I presented two sets of stimuli: i) videoclips extracted from popular comedies - aimed at eliciting spontaneous expressions (Miolla et al., 2022), and ii) static 2D pictures selected from the classic Ekman and Friesen dataset (Ekman & Friesen, 1976) to ask participants to produce a similar voluntary and controlled expression.

Experiments 2 were designed to manipulate the induction method. To this end, instead of presenting participants with videoclips that produced for instance hilarity without showing smiling faces (e.g., jokes by professional comedians), for the Spontaneous condition I selected real-life YouTube videos in which ordinary people shot frontally manifested the expression of happiness. For the Posed condition, I maintained the same procedure as in Experiment 1.

In Experimental Chapter 7, the same video clips adopted for Experiments 2 were used as experimental stimuli and I specifically devised a Continuous Emotion Rating task (CER) in which participants had to rate, after watching each video, how happy, surprised, disgusted, angry, sad, and scared they felt. Notably, these labels were not mutually exclusive (e.g., 7 happiness, 4 surprise, “not at all” for the other emotions).

Experimental Hypotheses

In general, I expected to find kinematic differences between spontaneous and posed expressions in both Experiment 1 and 2. As concern the comparison between the two Experiments, I further reasoned that if spontaneous expression is mediated by an automatic Involuntary Pathway, no kinematic differences should have emerged in this Condition depending on the method of induction (e.g., hilarious scenes vs. direct expressions of happiness), as long as both methods were effective. Crucially, I expected that observing dynamic faces shot frontally should have a Visuomotor Priming effect on the following Posed condition (i.e., voluntary mimicking) due to a carryover effect, even though stimuli were the same across Experiments (i.e., Ekman and Friesen dataset). Visuomotor priming is defined as the facilitation to perform an action congruent with the just-observed movement . To the best of my knowledge, Visuomotor Priming has never been studied in the context of Emotional Contagion.

PART 2

POSED VS. SPONTANEOUS EXPRESSIONS

3 | GENERAL METHODS

In this chapter the methods and the procedures which are common to all the experiments included in the Part 2 of the thesis will be described. The data were collected at the Neuroscience of Movement Laboratory at the Department of General Psychology - University of Padua. All protocols for containing the epidemiological emergency from COVID-19 were followed (Protocollo Contrasto e Contenimento Virus Sars-CoV-2 adopted by Rector's Decree N° 3093 of 24 September 2020 and subsequent updates).

ETHICS STATEMENT

All participants signed their written informed consent in accordance with the ethics approvals of both Experiments (N° 3580, 4539) issued by the Institutional Review Board at the University of Padua, in accordance with the Declaration of Helsinki (Sixth revision, 2008).

PARTICIPANTS

All the participants who took part in the present series of experiments were enrolled through advertisements on the University Website. All participants had a normal or corrected-to-normal vision, and they were naïve to the experimental design and study purpose.

RECORDING TECHNIQUES

Six infrared cameras (sampling rate 140 Hz), placed in a semicircle at a distance of 1–1.2 meters from the center of the room, captured the relative position of the infrared reflective markers (3 mm diameter) applied to the face of participants as displayed in Figure 1. Facial movements were recorded using a 3-D motion analysis system (SMART-DX, Bioengineering Technology and Systems [B|T|S]). The coordinates of the markers were reconstructed with an accuracy of 0.2 mm over the field of view. The standard deviation of the reconstruction error was 0.2 mm for the vertical (Y) axis and 0.3 mm for the two horizontal (X and Z) axis. The stimuli presentation was implemented using E-prime 2.0 which ensure synchronization with the SMART-D. During kinematical acquisition, participants' faces were videotaped frontally with a video camera (Logitech C920 HD Pro Webcam, Full HD 1080p/30fps) positioned above the monitor.

PROCEDURE

During all experiments, participants were tested individually in a dimly lit room. The stimuli presentation was implemented using E-prime V2.0. Participants underwent a single experimental session lasting approximately 20 minutes. They were seated in a height-adjustable chair in front of a monitor (40 cm from the edge of the table) and were free to move while observing selected stimuli displayed on the monitor (see Figure 3.1). Facial movements were recorded during two conditions: (i) Spontaneous condition, in which participants watched emotion-inducing videos (e.g., happiness-inducing videos) and reacted freely (i.e., they were not instructed to perform any specific response); (ii) Posed condition, in which participants were asked to perform the same expression on-demand while a static image of that expression was shown on the monitor, so as not to induce any emotional contagion. I chose classical images of expression of emotions from Ekman's dataset to compare my results with previous literature (Ekman & Friesen, 1976). In particular, in this condition, participants were instructed to mimic this expression for at least three times at their own pace. This procedure was aimed at inducing posed expressions without forcing the participants to respect time constraints (Miolla et al., 2021). The order of recording condition, spontaneous followed by posed, was the same for all participants (Sowden et al., 2021). In addition, in order to assess the emotional and cognitive components of empathy, each participant completed the Italian validated version of the Interpersonal Reactivity Index (IRI; Davis, 1983; Albiero et al., 2007; see below). Set-up and procedure were common to both experiments within each emotion-section.

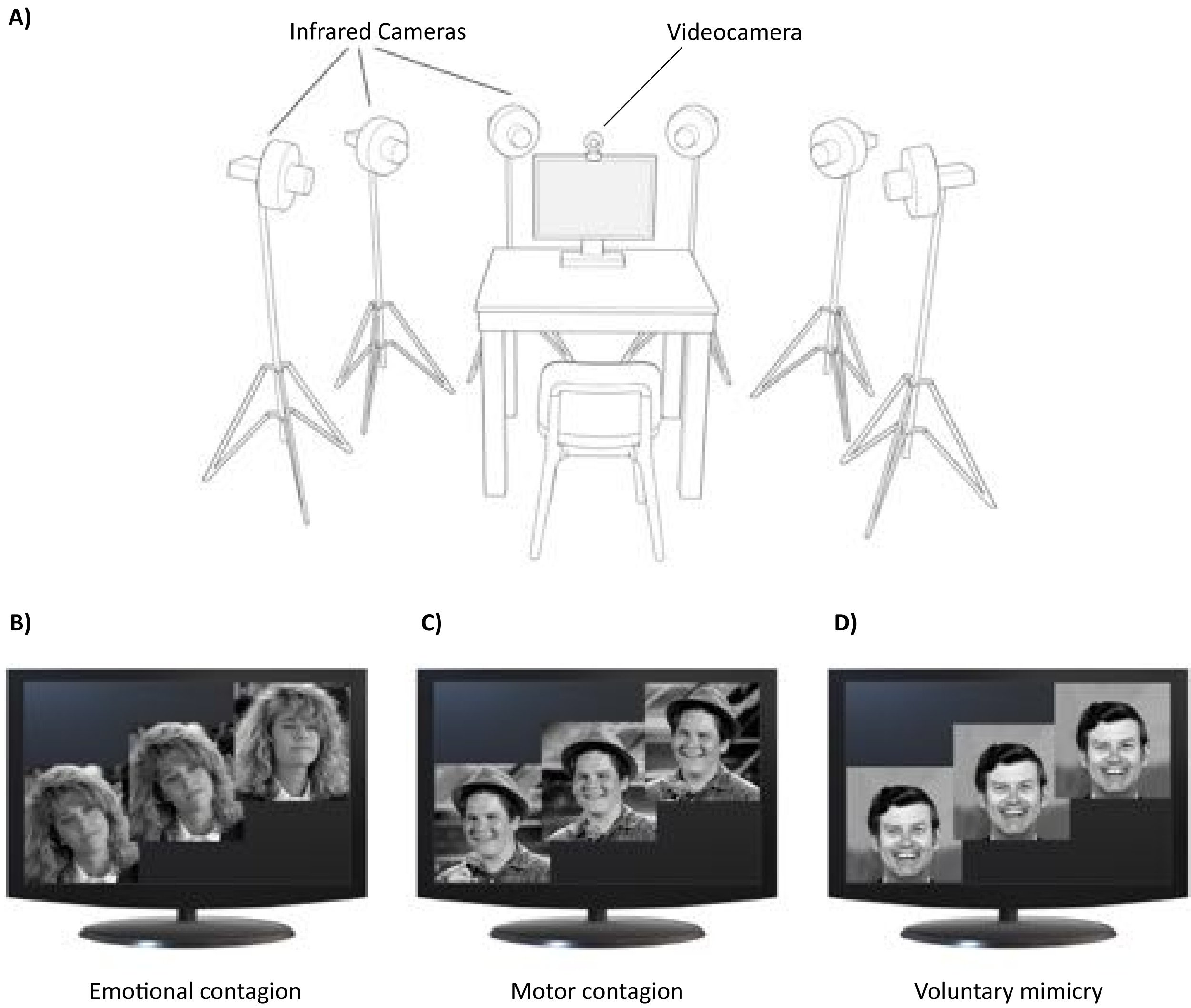

Figure 3.1. Schematic representation of the experimental set-up. Six infrared cameras recorded the movement of the markers placed on the face (panel A). The lower part of the figure shows the experimental conditions referring to the expression of happiness (Experimental chapter 1). In Experiment 1, participants watched clips of comedy films inducing Emotional contagion (panel B) and a static image of happiness that they had to mimic (panel D). In Experiment 2, participants watched videos extracted from YouTube showing happy faces, thus inducing Motor contagion (panel C) and the same static image of happiness (panel D). This experimental paradigm was common to all expressions.

Stimuli

Either video-clips or pictures were adopted as stimuli in the studies reported in the present thesis (a detailed description will be provided within each experimental chapter). For the Spontaneous condition, for experiment 1 of each chapter, I selected N=12 emotion-inducing videos from a recently-validated dataset structured to elicit genuine facial expressions (Miolla et al., 2022). Emotions were induced with movie scenes showing professional actors who performed, for example, hilarious scenes without exhibiting smiling faces. The length of the clips did not exceed 5 minutes according to the recommended size of the emotional video (Rottenberg et al., 2007). In the Experiment 2 of each chapter, I specifically manipulated the induction method to evaluate the effect of motor contagion on the posed and spontaneous expression of emotions. I selected video-clips from YouTube in which people were shot frontally while caught in a specific emotional condition. I selected video-clips based on their ability to trigger the mode of contagion through the spontaneous expression of emotional states (see Validation Study below). The duration of the video clips was from 19 to 59 seconds (average video duration for each emotion was: happiness=48.7 s; surprise=42.7 s; anger=51.0 s; disgust=38.3 s, sadness=43.7 s, fear=43.7 s). Videoclips were edited with VSDC video editor (https://www.videosoftdev.com/).

Validation study

I conducted six preliminary online validation studies on Qualtrics to select the most appropriate stimuli for the six Experiments on Motor Contagion. Participants were shown a brief sequence of videos and they had to rate how they felt after each video clip through a 9-point Likert scale, where 1 indicated not at all and 9 indicated very much. In addition, they were required to rate levels of valence (positive vs. negative) using a computerized version of the Self-Assessment Manikin – SAM (Bradley & Lang, 1994). Video-clips were presented in a pseudorandom order to avoid repetitions. Between different video clips, participants watched for 3 seconds a neutral image chosen by the IAPS (Lang et al., 1997) to ensure that the induction of emotions was not transmitted from one video-clip to the next.

Three-dimensional face navigation system: the Clepsydra Model

First of all, I identified the anatomical points relevant to the kinematic analysis of facial movement, based on previous literature (Lee et al., 2015; Popat et al., 2009, 2013; Sforza et al., 2010; Sidequersky et al., 2014). In particular, I relied on the areas identified by the Facial Action Coding System – FACS – a system for scoring facial expressions, originally developed for manual coding by human observers. I then created a detailed 3D model of the face with 18 markers (Figure 3.2 Panel A). I run an initial analysis on a sample of 10 participants with this model. Participants were shown three videoclips portraying happiness, surprise, and fear. I then refined the marker fitting based on the technical problems found in this sample. The goal was to identify a small number of markers that explained most of the variance and did not lead to fitting problems. Several markers were removed for technical reasons. In fact, the markers placed on exocanthion (Left and Right) during blinking were covered by crow's feet and signal was lost; the markers placed on nasion were spatially too close. In contrast, the markers placed on the lower part of the face labiale (superius and inferius), christal philtri (Left and Right), nasogenian (Left and Right), and chin were difficult to apply on the face and detect in subjects with beards. Finally, markers placed on zygomaticus (Left and Right) reported movement characterized by a high number of reference crossing, making the analysis unusable. A marker on the tip of the nose (TN) was added to consider possible differences across Left and Right hemiface. I then extracted five simple and relevant anatomical landmarks, to define a replicable and universal **Clepsydra Model**. Specifically, these points are: Left and Right Eyebrows (EB), Left and Right Cheilion (CH), and Tip of the Nose (TN). This model was designed with the purpose of analyzing separately the upper and lower face and comparing the Left and Right parts of the face (see Figure 3.2, Panel B). In particular, the relative movement of the two Cheilions and of the two Eyebrows was calculated to assess Proximal (i.e., closer to the center) movements (see red lines in Panel B), whereas the relative movement of these markers from the tip of the nose was calculated to assess Distal (i.e., further away from the center) movements (see yellow lines in Panel B). Notably, considering the relative distance between two points instead of single points allowed to neutralize possible head movements.

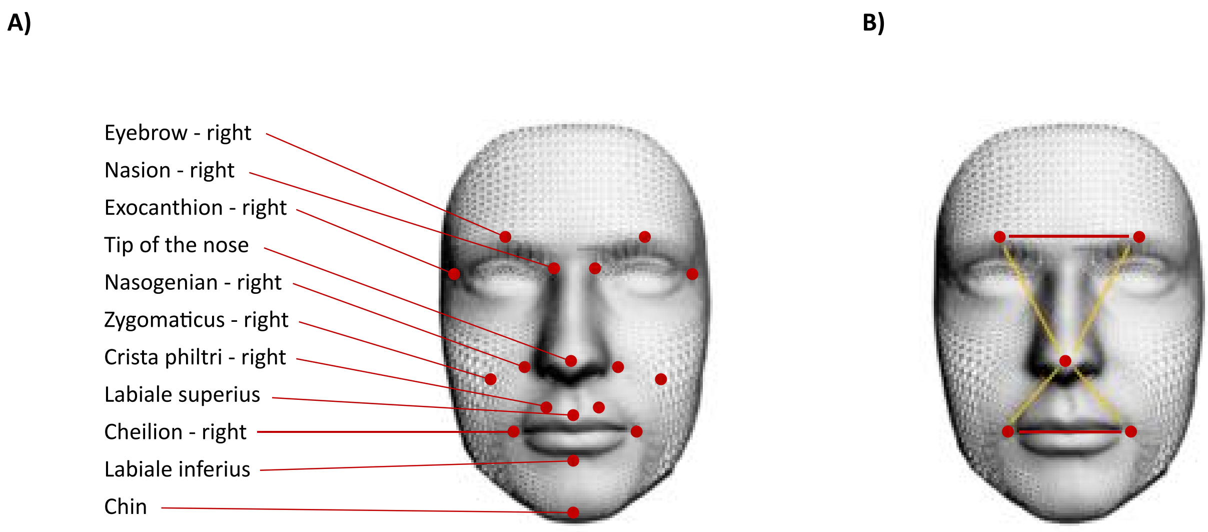

Figure 3.2. (A) Detailed model of the face: red dots represent key points for the expression of emotions (2 Eyebrow – Right and Left, 2 Nasion – Right and Left, 2 Exocanthion – Right and Left, 1 Tip of the nose, 2 Zygomaticus – Right and Left, 2 Nasogenian – Right and Left, 2 Crista philtri – Right and Left, 2 Cheilion – Right and Left, 1 Labiale superius, 1 Labiale inferior, 1 Chin). (B) The Clepsydra Model. Schematic representation of the infrared reflective marker on the considered anatomical landmarks (the red dots), they represent the key point for the expression of emotions; instead, the lines refer to the six facial distances. The lower and upper parts of the face are indicated by the two red line segments, while the Left and Right sides of the face refer to the four yellow lines.

DATA PROCESSING

After data collection, the SMART DX Tracker software package (B|T|S) was used to reconstruct the raw data for all trials of each participant to provide a three-dimensional reconstruction of marker positions as a function of time. The eyebrow markers were used to measure the upper part of the face, while the mouth corner markers were used to measure the lower part of the face. Finally, the nose tip marker was used as the midpoint of the face.

MEASURES OF INTEREST

Following the reconstruction procedures, I defined the dependent measurements in terms of displacement, time, Velocity, and Acceleration. Each expression was considered from the onset point to the maximum expression (i.e., the peak), following the speed profile over time (see Figure 3.3). Movement onset was calculated as the first time point at which the Mouth and the Eyebrows speed crossed a 0.2 mm/s threshold and remained above it for longer than 100 ms. Maximum expression was considered when the Mouth and the Eyebrows reached the maximum distance (i.e., the time at which the Mouth and Eyebrows speed dropped below the 0.2 mm/s threshold). When the same expressions were repeatedly performed within a trial, they were averaged in the analysis.

Specifically, I considered six pairs of markers:

- Upper part of the face:
  - Left and Right Eyebrows (EB)
  - Left Eyebrow and Tip of the Nose (Left-EB)
  - Right Eyebrow and Tip of the Nose (Right-EB)
- Lower part of the face:
  - Left and Right Cheilions (CH)
  - Left Cheilion and Tip of the Nose (Left-CH)
  - Right Cheilion and Tip of the Nose (Right-CH)

The following parameters were calculated on each pair of markers:

- Spatial parameters:
  - Maximum Distance (MD)
  - Delta Distance (DD)
- Velocity parameters:
  - Maximum Velocity (MV)
  - Maximum Acceleration (MA)
  - Maximum Deceleration (MDec, absolute value)

- Temporal parameters:

    - Time to Maximum Distance (TMD%)
    - Time to Maximum Velocity (TMV%)
    - Time to Maximum Acceleration (TMA%)
    - Time to Maximum Deceleration (TMDec%)

Delta Distance refers to the difference between the maximum and the minimum distance reached by two markers and was calculated to account for functional and anatomical differences across participants. Temporal parameters refer to the time at which spatial and speed parameters reached their peaks and were normalized with respect to movement time to account for individual speed differences.

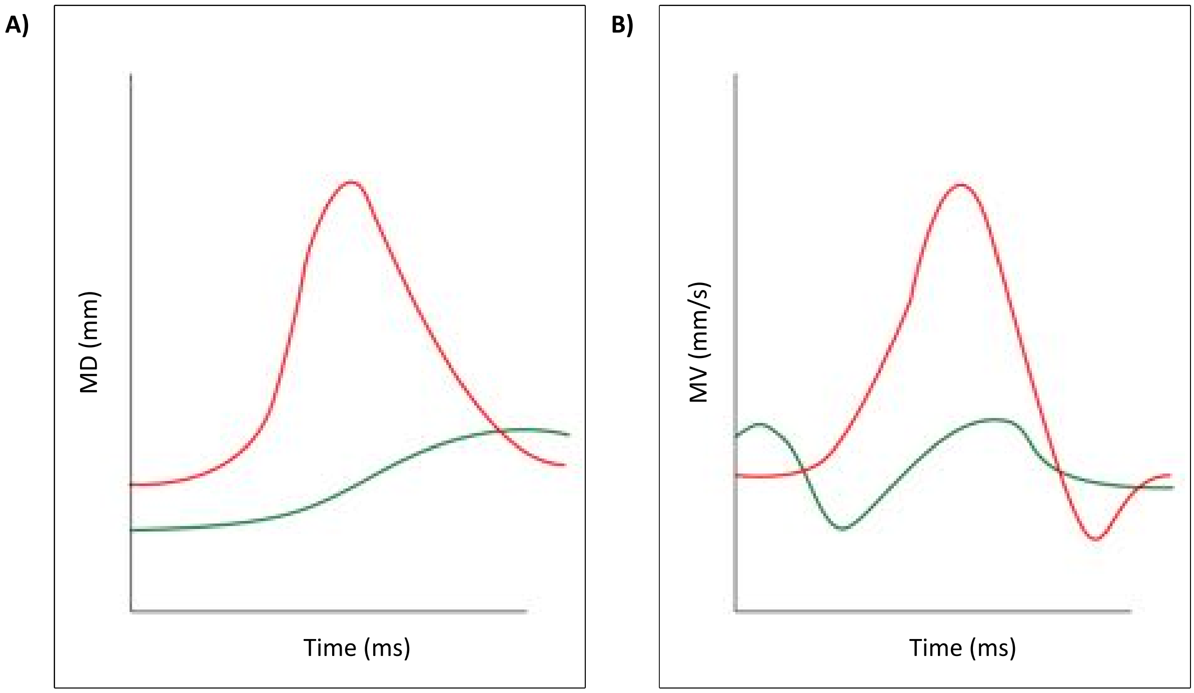

Figure 3.3. Mouth and Eyebrows widening profiles as a function of time. The dependent measures considered for the upper (green line) and lower (red line) part of the face. Maximum Distances are shown in panel A) and Maximum Velocities in panel B).

INTERPERSONAL REACTIVITY INDEX

The Italian validation of the Interpersonal Reactivity Index (IRI; Albiero et al., 2007; Davis, 1983; see Appendix I) is a 28-item self-report questionnaire to measure empathy answered on a 5-point Likert scale ranging from 0="does not describe me well" to 4="describes me very well". The IRI has four different subscales, each made up of seven different items, covering both the cognitive and emotional components of empathy. The cognitive component of empathy is measured by means of the perspective taking (PT) and fantasy (FS) scales, referring to the ability to adopt the viewpoint of others in everyday life, and to the tendency to project oneself into the place of fictional characters, respectively. The emotional component of empathy is measured by means of the empathic concern (EC) and personal distress (PD) scales, referring to the feelings of sympathy and concern for people involved in unpleasant experiences and the distress that results from witnessing another's negative emotional state, respectively.

DATA ANALYSIS

Data were analyzed using JASP version 0.16 statistical software (JASP Team, 2022). Data analysis was divided in two main parts: The first was aimed at testing if facial motion differs between spontaneous and posed emotional expressions; the second one was aimed at testing the differences between the Left and Right sides of the face during spontaneous and posed emotional expressions. The first part of the analysis consisted in fitting Linear Mixed-Effect Models having the two conditions (spontaneous and posed) as within fixed effects and Individuals as random effects. The Volk-Selke Maximum p-Ratio on the two-sided p-value was computed too, in order to quantify the maximum possible odds in favour of the alternative hypothesis over the null one (VS-MPR; Sellke et al., 2001) . During the second part of the analysis, a repeated-measures ANOVA with condition (spontaneous and posed) and side of the face (Left and Right) as within-subjects variable was performed together with planned orthogonal contrasts. For all statistical analyses, a significance threshold of $p < 0.05$ was set. Finally, to explore the crosstalk between IRI measures and kinematics, we performed a correlation analysis, using the Pearson correlation coefficient. Strong correlations were set from r=+/- 0.6 to r=+/- 0.79 and very-strong correlations were set from r=+/- 0.8 to r=+/- 1 (Akoglu, 2018). Finally, to explore the possible differences triggered by different induction methods in the expression of happiness (Posed and Spontaneous), I conducted a Comparison Analysis. I run a mixed analysis of variance with Experiment (1,2) as between-subjects factor and Condition (Posed, Spontaneous) and Side of the face (Left and Right) as within-subjects factor. Sample size was determined by means of GPOWER 3.1 (Erdfelder et al., 1996) based on previous literature. Since I used repeated-measures ANOVAs, I considered an effect size of 0.25, alpha=0.05 and power=0.8. The projected sample size needed with this effect size was N=20 for within group comparisons in each experiment. This sample size allowed for post-hoc comparisons, assuming alpha 0.05 and with a power 1-beta of 0.8.

4 | EXPERIMENTAL CHAPTER 1:

HAPPINESS

Happiness is the easiest facial expression to pose (Ekman et al., 1988). People pretend to smile for conveying enjoyment and positive feelings or reflecting politeness and affiliation during daily social interactions (Calvo et al., 2013; Ekman & Friesen, 2003). It has been argued that only a spontaneous smile produces crow's-feet wrinkles — the so-called Duchenne marker (Duchenne de Boulogne, 1990; Ekman et al., 1988, 1990; Frank et al., 1993). An increasing amount of evidence is however demonstrating that the Duchenne marker is not a reliable indicator. In fact, crow's-feet wrinkles could also be produced voluntarily by contracting the zygomatic major muscle in the absence of spontaneous happiness (Gunnery et al., 2013; Krumhuber & Manstead, 2009; Schmidt et al., 2006, 2009). A more rigorous approach and more consistent proofs are therefore necessary to characterize spontaneous from posed emotional facial expressions of happiness.

In general, I reasoned that for the posed condition the lower part of the face (i.e., mouth area) should present a wider and quicker smile amplitude than during spontaneous expressions, due to the fact that it is a social signal and as such it must be easily recognisable (Tramacere et al., 2018; Wegrzyn et al., 2017).

I further reasoned that if spontaneous expression is mediated by an automatic Involuntary Pathway, no kinematic differences should emerge depending on the method of induction (i.e., hilarious scenes vs. direct expressions of happiness), as long as both are effective. Instead, we expected that observing happy dynamic faces shot frontally should have a Visuomotor Priming effect on the following Posed condition due to voluntary mimicking.

EXPERIMENT 1

METHODS

Participants

Seventeen participants (13 females and 4 males) aged between 21 and 32 years ($Mean_{age}$=24.75, SD=3.04) were recruited. Three participants were subsequently excluded due to poor registration for face tracking.

Stimuli and Procedure

For the Posed condition I adopted a static picture of happiness. Spontaneous happiness was instead elicited by using video clips inducing emotional contagion.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of all the spatial and Velocity parameters when the participants performed a posed smile, compared to when they smiled spontaneously (MDCH: $F_{(1,16)}$=17.721, p<0.001, VS-MPR=75.614; DDCH: $F_{(1,16)}$=9.901, p<0.01, VS-MPR=11.615; MVCH: $F_{(1,16)}$=16.966, p<0.001, VS-MPR=64.217; MACH: $F_{(1,16)}$=9.283, p=0.009, VS-MPR=8.908; MDecCH: $F_{(1,16)}$=12.146, p=0.004, VS-MPR=17.990; Figure 4.1 A-E). None of the temporal parameters revealed significant differences through conditions (all p_s > 0.05).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the Maximum Distance of the Eyebrows when the participants performed a posed smile, compared to when they smiled spontaneously (MDEB: $F_{(1,16)}$=20.613, $p<0.001$, VS-MPR=137.386; Figure 4.1 F). Velocity and temporal parameters did not result statistically significant (all $p_s > 0.05$).

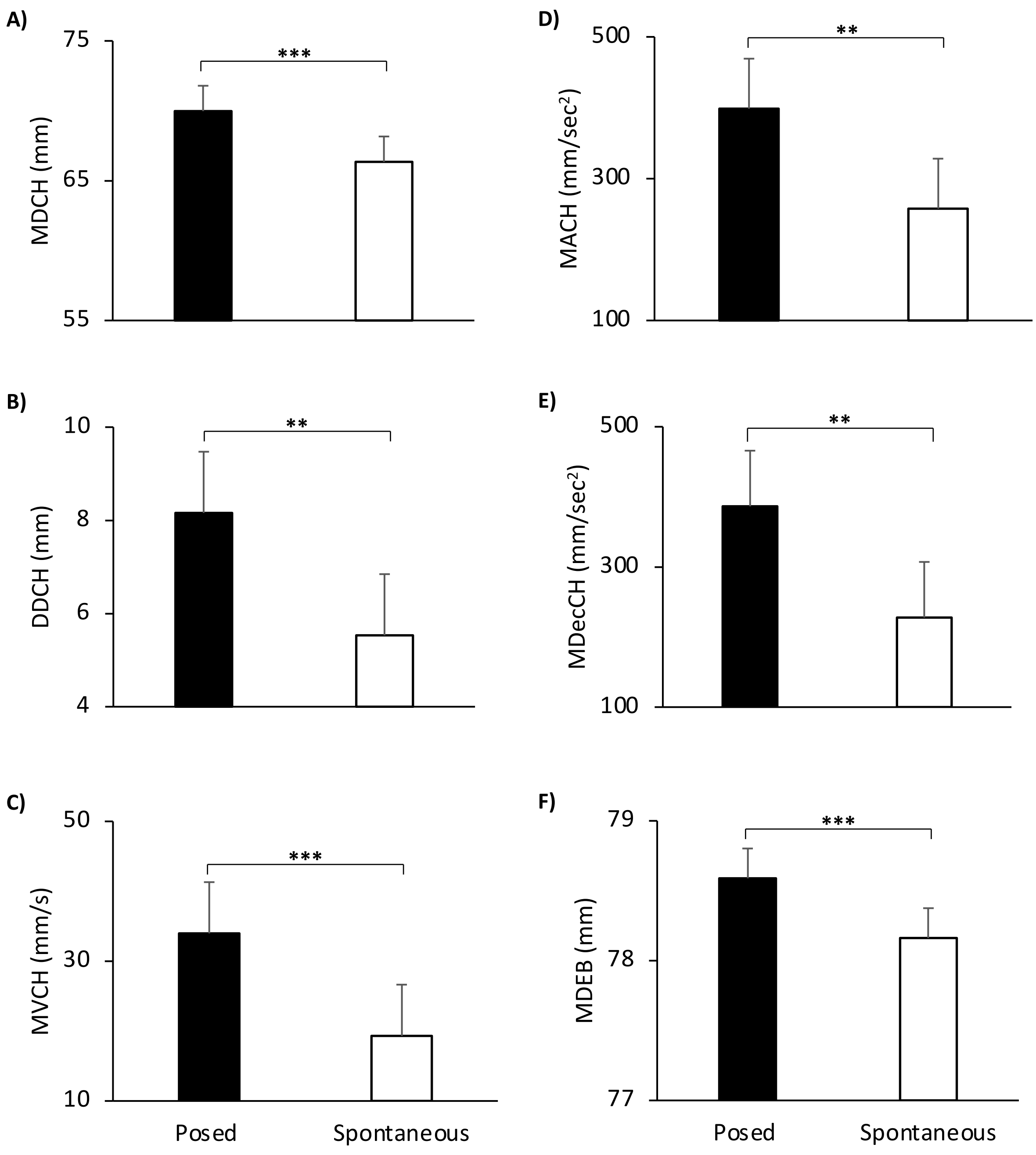

Figure 4.1. Graphical representation of spatial and speed components of movement in the lower part (i.e., Cheilion markers) and upper part (i.e., Eyebrow markers) of the face during Posed and Spontaneous expressions of happiness. (A) Maximum Distance (MDCH), (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH); (D) Maximum Acceleration (MACH); (E) Maximum Deceleration (MDecCH); (F) Maximum Distance of the Eyebrows (MDEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***= p<0.001).

CORRELATIONS BETWEEN IRI AND KINEMATICS MEASURES

Positive correlations emerged between IRI measurements and both spatial (MD, DD) and Velocity (MV) kinematic parameters, but only in the lower part of the face (i.e., Cheilion markers). In the posed condition, strong positive correlations emerged between MD and the FS and EC subscales. A positive correlation was found between DD and PD. In particular, strong and reliable correlations were found on the FS subscale for the Spontaneous condition. Negative correlation is finally noted between MDec and EC (Table 4.1).

Table 4.1. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions of happiness.

	IRI		MD CH	DD CH	MV CH	MA CH	Mdec CH
Posed	COG	PT	-0.019	-0.524	-0.372	-0.249	0.165
		FS	**0.691***	0.041	-0.192	-0.368	0.335
	EMO	EC	**0.732***	0.493	0.227	-0.145	0.07
		PD	0.232	**0.666***	0.418	0.121	-0.141
Spontaneous	COG	PT	0.126	-0.139	-0.44	-0.297	0.273
		FS	**0.773***	**0.672***	**0.748***	0.268	**-0.587***
	EMO	EC	0.47	0.23	**0.584***	0.341	**-0.617***
		PD	0.029	0.035	0.527	0.435	-0.454

REPEATED-MEASURES ANOVA: POSED VS. SPONTANEOUS DISTAL MOVEMENTS

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

A repeated-measures ANOVA on the movements of each Left and Right Cheilion from the Tip of the Nose during Posed and Spontaneous conditions was run. The analysis revealed a significant main effect of the Condition for MD, DD, MV, MA, MDec, and TMA%. This movement was more speeded and reached a greater and earlier Acceleration peak, followed by an increased Deceleration peak (MD: $F_{(1,16)}=21.440$, $p<0.001$, VS-MPR=161.690, $\eta^2_p=0.573$; DD: $F_{(1,16)}=8.221$, $p=0.011$, VS-MPR=7.325, $\eta^2_p=0.339$; MV: $F_{(1, 16)}=10.595$, $p=0.005$, VS-MPR=13.958, $\eta^2_p=0.398$; MA: $F_{(1,16)}=8.523$, $p=0.012$, VS-MPR=6.952, $\eta^2_p=0.396$; MDec: $F_{(1, 16)}=6.491$, $p=0.024$, VS-MPR=4.073, $\eta^2_p=0.333$). A significant main effect of Side of the face was found for TMDec% ($F_{(1,16)}=24.037$, $p<0.001$, VS-MPR=188.689, $\eta^2_p=0.632$). The Deceleration peak was reached earlier in the Right than in the Left side of the face (Figure 4.2). Interaction with Side of the face was not significant, nor were the main effects or interactions of the other dependent measures significant (all $p_s > 0.05$).

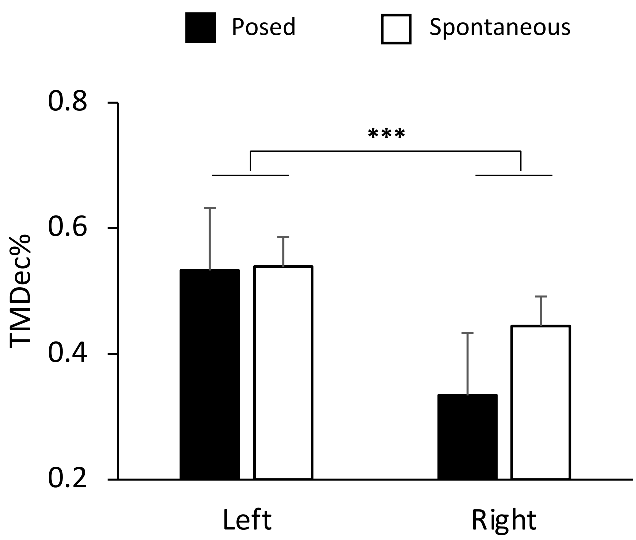

Figure 4.2. The graph shows the Time to Maximum Deceleration (TMDec%) of the Left and Right Cheilion to the tip of the nose through the conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (***=p<0.001).

Planned orthogonal contrasts were analysed according to the schema displayed in Table 4.2 for MDCH and MVCH.

Table 4.2. Schema of the planned orthogonal contrasts for the MDCH and MVCH variables. Contrast 1 was calculated between different conditions (Posed=1, Spontaneous=-1). Contrast 2 was calculated between Right Posed (-1) and Right Spontaneous (1) expressions. Contrast 3 was calculated between Left Posed (-1) and Left Spontaneous (1) expressions.

Side of the face	Expression	Contrast 1	Contrast 2	Contrast 3
Right	Posed	1	-1	0
Left	Posed	1	0	-1
Right	Spontaneous	-1	1	0
Left	Spontaneous	-1	0	1

The first comparison was conducted between posed and spontaneous expressions, irrespective of the side of the face. The other comparisons were applied to the Right and to the Left sides of the face, respectively (2nd and 3rd contrasts). Results showed that for both MDCH and MVCH, a significant difference exists between posed and spontaneous expressions for both sides of the face. More precisely, the value of MDCH was higher in posed expressions both for the Right ($t_{17.981}$=–4.464, $p<0.001$) and for the Left side of the face ($t_{17.981}$=-4.521, $p<0.001$). Similar results were observed also for the MVCH variable with higher values for posed expressions both on the Right ($t_{21.311}$=-3.289, $p<0.001$) and on the Left side of the face ($t_{21.311}$=-2.728, $p<0.001$).

Upper part of the face - Left and Right Eyebrows (LeftEB, RightEB)

The repeated-measures ANOVA on the movement of each Eyebrow from the Tip of the Nose revealed a significant main effect of the Condition for MD ($F_{(1,16)}$=12.298, $p<0.003$, VS-MPR=21.580, η^2_p=0.045). Both the Eyebrows were more distal for the Posed than for the Spontaneous condition. Interaction with Side of the face was not significant, nor were the main effects or interactions of the other dependent measures significant (all $p_s>0.05$). Planned orthogonal contrasts were computed on MD according to the same schema displayed in Table 1 and confirmed previous results. Markers on Left and Right Eyebrows were more distal for Posed than Spontaneous expressions both in the Right ($t_{22.995}$=-3.676, $p<0.001$) and Left sides of the face ($t_{22.995}$=-2.648, $p<0.001$).

Interim Discussion – Experiment 1

Proximal Movements

Results from the Linear mixed-effects models on proximal movements indicate that posed expressions of happiness were performed with larger smile amplitude, higher Velocity and Deceleration peaks compared to spontaneous expressions. Moreover, I found that posed expressions entailed an increased Distance of the Eyebrows, but no difference whatsoever in peak Velocities. This seems to suggest that activating the Voluntary Pathway on command to perform a posed expression of happiness mainly influenced the lower part of the face and to a lesser extent the upper part of the face.

IRI

Strong correlations ($r \geq 0.6$) between statistically significant parameters for the expressions of happiness in Experiment 1 and the IRI questionnaire were found only in the lower part of the face. For the Posed condition, there were strong and positive correlations between the Maximum Distance and FS + EC subscales, and between the Delta Distance and the PD subscale. For the Spontaneous condition, instead, correlations also extended to the speed parameters. In particular, results showed a strong correlation between Delta Distance and the FS subscale (i.e., Cognitive scale of the IRI) and very strong ($r \geq 0.8$) correlations between this subscale and both the Maximum Distance and Maximum Velocity. A strong negative correlation was also found between the Deceleration peak and the EC subscale.

Distal movements

Results from the repeated-measure ANOVA on distal movements confirmed all these results, and they did not show any differences across the Left and Right sides of the face, except for the Time to Maximum Deceleration (%). In particular, the Deceleration peak was reached earlier in the Right Cheilion than in the Left Cheilion.

Emotional Contagion

These results support the concept that facial expressions of happiness are predominantly organized in the lower part of the face (Ross et al., 2016).

According to Ekman and colleagues (Ekman et al., 1988; Ekman & Friesen, 1982), a false (non-Duchenne) smile would only involve the lower face area. According to Ross and colleagues, instead, the difference between a felt (Duchenne) versus a fake smile would be revealed by the side of the face initiating the smile (Ross et al., 2016). Here, I found that posed expressions of happiness are also characterised by an increased Distance between the Eyebrows.

As concerns the lateralization topic, only a temporal parameter was able to distinguish between Left and Right sides of the face: an early peak of Deceleration in the right corner of the mouth seems to characterize the expressions of happiness induced by Emotional Contagion regardless of whether they are posed or spontaneous. Indeed, the interaction Condition by Side of the face was not significant.

These results partially contrast also with that suggested by Schmidt and colleagues (2006), who showed lateralization for spontaneous expression.

It should be noted, however, that all these Authors adopted different paradigms, techniques, stimuli, and methods of induction. Once again, I emphasize the importance of using dynamic stimuli and a unique method in order to arrive at shared results.

Experiment 2

Methods

Participants

Twenty participants (12 females, 8 males) aged between 20 and 29 years ($Mean_{age}$=23.01, SD=2.13) voluntarily participated in this study. None of them took part in Experiment 1.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous happiness was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 58 healthy volunteers (44 females, 13 males, 1 non-binary; age=18-60 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods). The happiness scores of each video clip were significantly higher than the midpoint of the scale (all p_s<0.001) and I selected the three video clips with the highest scores on the Likert and the SAM scales.

RESULTS

LINEAR MIXED EFFECT MODELS: SPONTANEOUS VS. POSED PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixer Effect Models revealed a significant effect of Condition with an increase of all the spatial and Velocity parameters when the participants performed a posed smile, compared to when they smiled spontaneously (MDCH: $F_{(1,24)}$=55.241, p<0.001, VS-MPR=203200.396; DDCH: $F_{(1,24)}$=72.352, p<0.001, VS-MPR=1911000; MVCH: $F_{(1,24)}$=133.321, p<0.001, VS-MPR=547600000; MACH: $F_{(1,24)}$=41.907, p<0.001, VS-MPR=25187.354; MDecCH: $F_{(1,24)}$=36.120, p<0.001, VS-MPR=8779.579; Figure 4.3 A-E). In addition, this movement reached an earlier Velocity peak, followed by an earlier Deceleration peak (TMV%CH: $F_{(1,24)}$=5.661, p=0.026, VS-MPR=3.916; TMDec%CH: $F_{(1,24)}$= 6.747, p=0.016, VS-MPR=5.585; Figure 4.3 F-G). None of the remaining temporal parameters revealed statistically significant differences through conditions (all p_s > 0.05).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the Maximum Distance of the Eyebrows when the participants performed a posed smile, compared to when they smiled spontaneously (MDEB: $F_{(1,24)}$=10.278, p=0.004, VS-MPR=17.424; Figure 4.3 H). Velocity and temporal parameters did not result statistically significant (all p_s > 0.05).

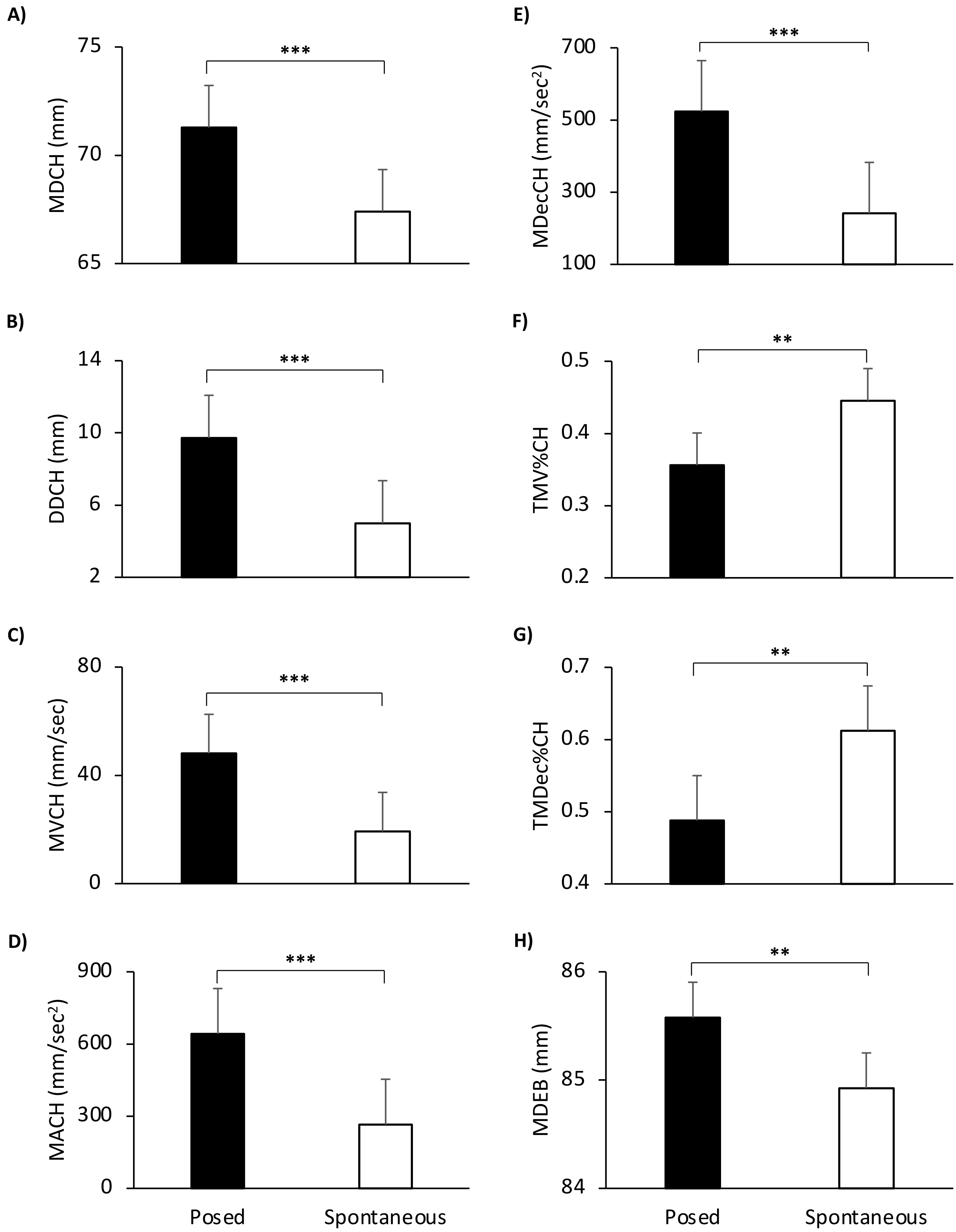

Figure 4.3. Graphical representation of spatial and speed components of movement in the lower part (i.e., Cheilion markers) and upper part (i.e., Eyebrow markers) of the face during Posed and Spontaneous expressions of happiness. (A) Maximum Distance (MDCH), (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH); (D) Maximum Acceleration (MACH); (E) Maximum Deceleration (MDecCH); (F) Time to Maximum Velocity (TMV%CH); (G) Time to Maximum Deceleration (TMDec%CH); (H) Maximum Distance of the Eyebrows (MDEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***= p<0.001).

Correlations between IRI and kinematics measures

Only a strong negative correlation emerged between the PD subscale and TMV% of the lower part of the face (i.e., Cheilion markers) (Table 4.3).

Table 4.3. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions of happiness

EXPRESSION	IRI		MD CH	DD CH	MV CH	MA CH	MDec CH	TMV% CH	TMA% CH	TMDec% CH	MD EB
Posed	COG	PT	0.080	0.072	0.004	0.026	-0.092	0.258	0.280	0.349	-0.070
		FS	0.249	0.072	0.078	0.018	0.089	0.222	0.210	0.387	0.130
	EMO	EC	0.200	0.096	0.040	0.002	-0.024	-0.046	-0.087	-0.060	0.027
		PD	0.006	-0.073	0.059	0.094	0.123	-0.227	-0.088	-0.148	-0.198
Spontaneous	COG	PT	0.254	0.240	0.079	-0.066	-0.030	0.073	0.025	0.173	-0.041
		FS	0.191	-0.151	-0.180	-0.182	0.106	0.215	0.227	0.291	0.124
	EMO	EC	0.198	-0.250	-0.237	-0.214	0.193	-0.055	-0.180	-0.048	0.044
		PD	-0.027	0.027	0.091	0.395	-0.171	**-0.550 ***	-0.004	-0.377	-0.143

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, Right CH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,24)}$=37.578, p<0.001, VS-MPR=11506.624, η^2_p=0.610) and a significant interaction Condition by Side of the Face (MD: $F_{(1,24)}$=11.060, p<0.01, VS-MPR=22.160, η^2_p=0.315) were found. Post hoc contrasts confirmed that a posed smile was wider compared to a spontaneous smile both in the Left and Right sides of the face. They also showed that a posed expression entailed a more distal movement of the LeftCH than did a spontaneous expression on the RightCH (all p_s<0.001; Figure 4.4 A).

Maximum Velocity (MV) | A significant main effect of the Condition ($F_{(1,24)}$=37.578, p<0.001, VS-MPR=11506.624, η^2_p=0.610) was found. The peak Velocity was higher when the smile was posed than when it was spontaneous (19.458 and 8.899 mm/sec, respectively).

Time to Maximum Distance (TMD%) | Two significant main effects of Condition ($F_{(1,24)}$=24.336, p<0.001, VS-MPR=753.111, η^2_p=0.356) and Side of the face ($F_{(1,24)}$=5.821, p<0.05, VS-MPR=4.13, η^2_p=0.195) were found. The Left Cheilion reached its peak Distance later than the Right Cheilion (82.7% vs. 79.4%) in both conditions.

Time to Maximum Acceleration (TMA%) | A significant main effect of Condition ($F_{(1,24)}$=11.700, p=0.002, VS-MPR=26.900, η^2_p=0.328), Side of the face ($F_{(1,24)}$=7.249, p=0.013, VS-MPR=6.623, η^2_p=0.232), and an interaction Condition by Side of the face ($F_{(1,24)}$=4.306, p<0.05, VS-MPR=2.494, η^2_p=0.152; Figure 4.4 B) were found. Post hoc contrasts showed that the peak Acceleration of the LeftCH in the Posed condition was earlier (28.5%) both in comparison with the RightCH (37%, p=0.014) and compared with the Spontaneous condition (49.2%, p=0.002).

Time to Maximum Deceleration (TMDec%) | A significant main effect of Condition ($F_{(1,24)}$=11.391, p=0.003, VS-MPR=24.506, η^2_p=0.322), Side of the face ($F_{(1,24)}$=56.332, p<0.001, VS-MPR=237609.025, η^2_p=0.701) and the interaction Condition by Side of the Face ($F_{(1,24)}$=7.325, p=0.012, VS-MPR=6.792, η^2_p=0.234; Figure 4.4 C) were found. Post hoc contrasts showed that the peak Deceleration of the RightCH in the Posed condition was earlier (28.5%) both in comparison with the LeftCH (55.2%, p<0.001) and compared with the Spontaneous condition (49.6%, p<0.001).

The effects on DD, MA, MD, and TMV% parameters were not statistically significant (all $p_s>0.05$).

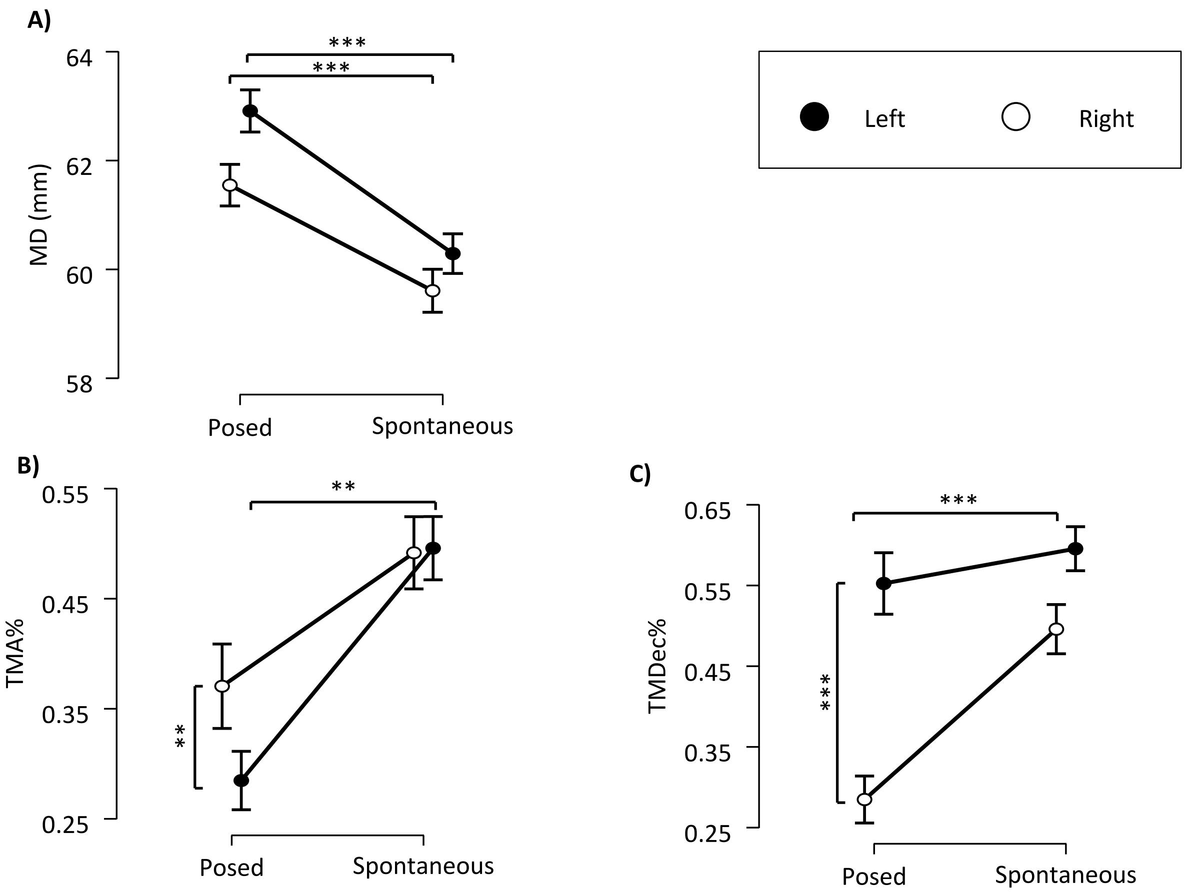

Figure 4.4. The graphs show: (A) the Maximum Distance (MD), and the percentage of time at which peaks of (B) Acceleration (TMA%) and (C) Deceleration (TMDec%) reached by the Left and Right Cheilions occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=$p<0.01$; ***= $p<0.001$).

The upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

The repeated-measures ANOVA on the movement of each Eyebrow from the Tip of the Nose did not show any statistically significant effect (all $p_s>0.05$).

Interim Discussion – Experiment 2

Proximal Movements

In Experiment 2, I found a consistency with Experiment 1 in the spatial and speed components of proximal movements. Indeed, the Maximum Distance of the corners of the mouth and its Delta, and the Velocity, Acceleration and Deceleration peaks were higher for the Posed than for the Spontaneous condition. In this experiment, also the temporal parameters were statistically significant. In fact, the peaks of Velocity and Deceleration were delayed for spontaneous compared to posed expressions. In the upper part of the face, the posed expressions showed higher values for the maximum Distance compared to the spontaneous expressions.

IRI

Only one strong correlation ($r \geq 0.6$) was found between statistically significant parameters for the expressions of happiness in Experiment 2 and the IRI questionnaire. In particular, during spontaneous expressions of happiness, a negative correlation was found between the time at which the peak Velocity was reached and the Personal Distress subscale (i.e., Emotional scale of the IRI).

Distal Movements

Results from the repeated-measure ANOVAs on distal movements of the Cheilions showed a wider and anticipated peak Distance, and a greater peak Velocity for posed than for spontaneous expressions.

As concerns the lateralization topic, the peak Distance was reached earlier in the Right than in the Left corner of the mouth for both conditions. Whereas only for the Posed condition the peak Acceleration was reached earlier in the Left corner and the peak Deceleration was reached earlier in the Right corner. Furthermore, there were two significant interactions between Condition and Side of the face: the Acceleration peak of the LeftCH and the Deceleration peak of the RightCH were anticipated for the Posed compared to the Spontaneous condition.

Motor Contagion

In accordance with Experiment 1, these results support the concept that facial expressions of happiness are predominantly organized in the lower part of the face (Ross et al., 2016). In fact, Distances and Velocities between the corners of the mouth were greater during posed than spontaneous expressions, and the same was true for the eyebrows Distance. In addition, adopting a method that induced Motor Contagion also produced an effect on the time parameters: posed expressions of happiness induced after observing other people smiling were characterised by two early peaks of Distance and Deceleration in the RightCH compared to spontaneous expressions. Overall, these results suggest a clear effect of Visuomotor Priming: posed smiles were anticipated after observing videos of happiness expressions shot frontally.

Interestingly, temporal parameters also showed two significant interactions between Condition and Side of the face. In particular, posed expressions of happiness were characterised by anticipated peaks of Acceleration (LeftCH) and Deceleration (RightCH) compared to the spontaneous expressions. It seems that compared with the felt smile, the on-demand smile involves an initial acceleration of the left corner of the mouth, while a deceleration of the right corner occurs in the second phase of the movement, after the velocity peak. This result would be in line with Ross and colleagues' hypothesis that it is precisely the temporal dynamics of the movement that distinguishes true and false smiles (Ross et al., 2016). It should be noted, however, that this result holds only for smiles elicited by the inductive Motor Contagion method. Whereas for Emotional Contagion (Exp 1), no temporal difference was found for posed smiles between the two sides of the face. This result raises the question of the need to compare different induction styles in depth: this may be the key to resolving the apparent conflict between various theories that have attempted to discriminate true and false expressions.

Comparison analysis – Comparison Analysis

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Maximum Distance (MDCH) | A significant main effect of Condition was found ($F_{(1, 40)}$=62.420, p<0.001, VS-MPR=16520000, η^2_p=0.609). Posed expressions were wider than spontaneous smiles (70.630 and 66.874 mm, respectively).

Delta Distance (DDCH) | A significant main effect of Condition was found ($F_{(1, 40)}$=58.409, p<0.001, VS-MPR=7640000, η^2_p=0.609). The interaction between Experiment and Condition was also statistically significant ($F_{(1,40)}$=4.777, p=0.035, VS-MPR=3.151, η^2_p=0.107). Post hoc comparisons revealed that posed smiles performed in Experiment 1 had a larger range than spontaneous smiles (8.159 mm vs 5.532 mm, respectively; p=0.006) The same occurred for Experiment 2: posed smiles had a larger range than spontaneous smiles (9.719 mm vs 4.988 mm, respectively; p<0.001; Figure 4.5 A).

Maximum Velocity (MVCH) | A significant main effect of Condition was found ($F_{(1, 40)}$=106.536, p<0.001, VS-MPR= 17150000000, η^2_p=0.727). The interaction between Experiment and Condition was also significant ($F_{(1,40)}$=11.314, p=0.002, VS-MPR=33.842, η^2_p=0.220). Post hoc comparisons revealed that posed smiles performed in Experiment 1 had a higher peak of Velocity than spontaneous smiles (33.975 mm/sec vs 19.311 mm/sec, respectively; p<0.001) The same occurred for Experiment 2: posed smiles had a higher peak of Velocity than spontaneous smiles (48.121 mm/sec 19.278 mm/sec, respectively; p<0.001). Moreover, posed smiles performed in Experiment 2 showed an increased Maximum Velocity with respect to Experiment 1 (p=0.002; Figure 4.5 B).

Maximum Acceleration (MACH) | A significant main effect of Condition was found ($F_{(1, 40)}$=37.273, p<0.001, VS-MPR=55661.495, η^2_p=0.502). The interaction between Experiment and Condition factors was also significant ($F_{(1,40)}$=7.981, p=0.008, VS-MPR=9.948, η^2_p=0.177). Post hoc comparisons revealed that posed smiles performed in Experiment 2 showed an increased peak of Acceleration than spontaneous smiles (643.438 mm/sec^2 vs 265.036 mm/sec^2, respectively; p<0.001). Moreover, the peak of Acceleration was significantly higher for posed expressions in Experiment 2 than in Experiment 1 (643.438 vs 407.166 mm/sec^2, respectively; p=0.006; Figure 4.5 C).

Maximum Deceleration (MDecCH) | A significant main effect of Condition was found ($F_{(1,40)}$=38.022, p<0.001, VS-MPR=66459.412, η^2_p=0.507). The interaction between Experiment and Condition factors was not significant (p>0.05).

Time to Maximum Acceleration (TMA%CH) | A significant main effect of Condition was found ($F_{(1,40)}$=4.340, p<0.05, VS-MPR=2.661, η^2_p=0.108). The interaction between Experiment and Condition factors was not significant (p>0.05).

Time to Maximum Deceleration (TMDec%CH) | A significant main effect of Condition was found ($F_{(1,40)}$=6.829, p<0.05, VS-MPR=66459.412, η^2_p=0.159). The interaction between Experiment and Condition factors was not significant (p>0.05).

The effects on TMD%CH and TMV%CH were not statistically significant (all p_s>0.05).

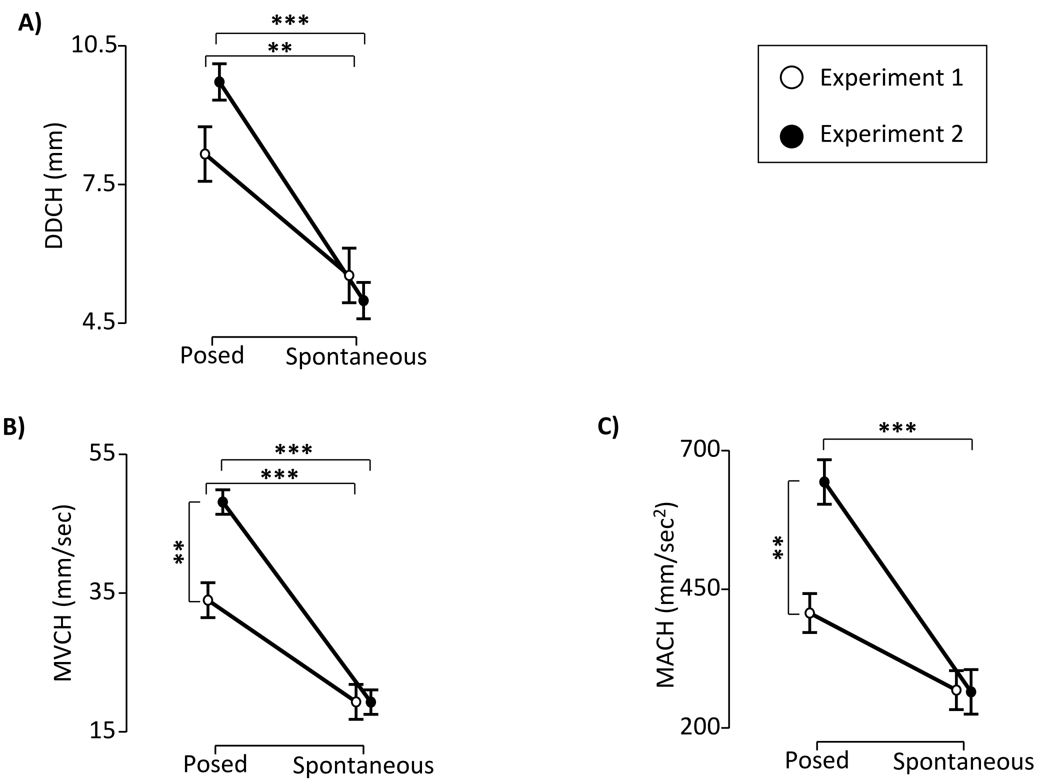

Figure 4.5. The graphs show: (a) the delta Distance (DD), and peaks of (b) Velocity (MV) and (b) Acceleration (MA) in the lower part (i.e., Cheilion markers, CH) of the face. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***= p<0.001).

Upper part of the face – Eyebrows (EB)

Maximum Distance (MD) | A significant main effect of Condition was found ($F_{(1, 40)}$=17.299, $p<0.001$, VS-MPR=257.177, η^2_p=0.302). Even in the upper part of the face, posed expressions were wider than spontaneous ones (82.083 and 81.543 mm, respectively). None of the remaining parameters was significant (all $p_s>0.05$).

Mixed ANOVA: Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | A significant main effect of Condition was found ($F_{(1, 40)}$=54.026, p<0.001, VS-MPR= 3174000, η^2_p=0.575). The 2-way interaction between Condition and Side of the face was significant ($F_{(1,40)}$=5.728, p=0.021, VS-MPR=4.460, η^2_p=0.125). The 3-way interaction between Condition, Side of the face and Experiment was also significant ($F_{(1,40)}$=5.027, p=0.031, VS-MPR=3.451, η^2_p=0.122). Post hoc Bonferroni-corrected comparisons revealed that the LeftCH was more distal for posed than spontaneous smiles in both Experiment 1 (p=0.006) and 2 (p<0.001). The same occurred for the RightCH: it was more distal for posed than spontaneous smiles both in Experiment 1 (p=0.007) and Experiment 2 (p<0.001) (Figure 4.6). There were other three interactions, but they were not relevant.

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1, 40)}$=29.976, p<0.001, VS-MPR=11081.898, η^2_p=0.428). Posed expressions had an increased range of mouth widening than spontaneous expressions (2.859 and 1.589 mm, respectively).

Maximum Velocity (MV) | The main effect of Condition was significant ($F_{(1, 40)}$=39.621, p<0.001, VS-MPR=130131.798, η^2_p=0.498). The peak speed was higher for posed than for spontaneous expressions (17.880 and 8.705 mm/sec, respectively).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1, 40)}$=11.364, p=0.002, VS-MPR=32.895, η^2_p=0.235). The peak Acceleration was higher for posed than for spontaneous expressions (320.982 and 170.343 mm/sec^2, respectively).

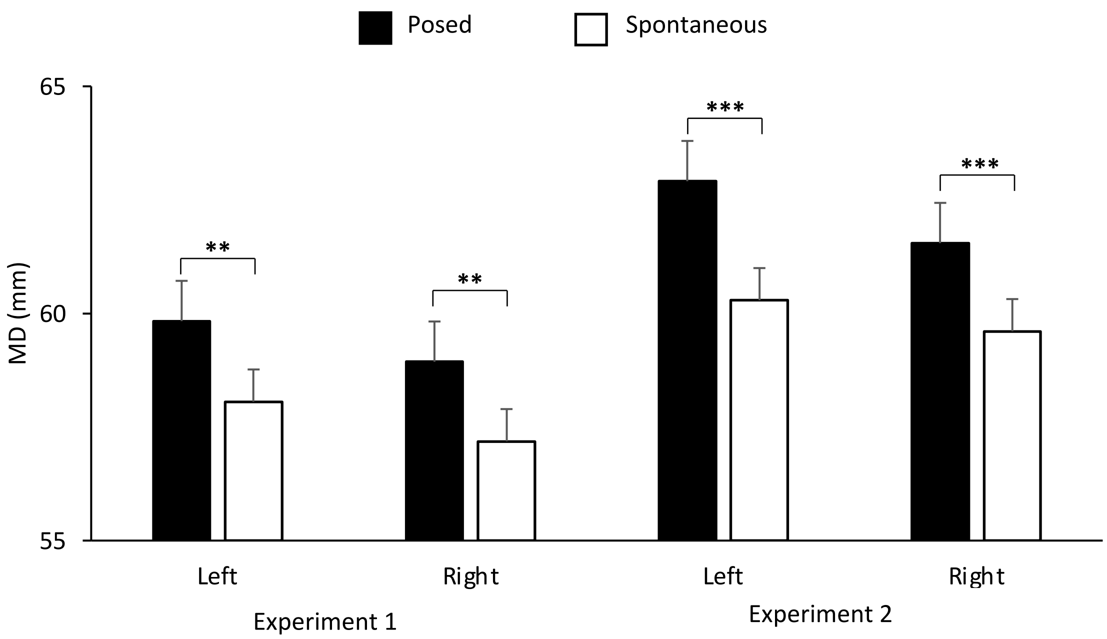

Figure 4.6. The bar graph represents the Maximum Distance in the upper part of the face during Posed and Spontaneous expressions of happiness in Experiments 1 and 2. Significant comparisons for the three-way interaction Condition by Side of the face by Experiment are shown. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.01; **=p<0.01).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Maximum Distance (MD) | The main effect of Condition was significant ($F_{(1, 40)}$=9.929, p=0.003, VS-MPR=20.665, η^2_p=0.199). Eyebrows were more distal for posed than for spontaneous expressions (78.642 and 78.143 mm, respectively).

Interim Discussion – Comparison Analysis

Results from two Experiments demonstrated that both proximal and distal facial movements provide relevant and consistent details to characterize and distinguish between spontaneous and posed expressions of happiness.

Proximal movements

In line with our predictions, results revealed that the speed and amplitude of the mouth as it widens into a smile are greater in posed than genuine happiness. In particular, a posed smile is characterized by an increase of the smile amplitude, speed and deceleration, as indicated by the Cheilion pair of markers. As concern the upper part of the face, results showed a similar increase of the Maximum Distance of the Eyebrows when the participants performed a posed smile compared to when they smiled spontaneously. It should be noted, moreover, that Motor Contagion had a specific effect on the speed parameters: posed smiles were quicker and more accelerated in Experiment 2 than in Experiment 1.

Distal movements

Taking hemiface into consideration, results from the repeated-measure ANOVA showed no main effect or interaction between Experiment and Side of the face.

Emotional vs. Motor Contagion

When comparing the two Experiments, results showed that posed smiles were quicker and more accelerated in Experiment 2 than Experiment 1. These data suggest that the on-demand smile was more facilitated after observing videoclips of genuine happiness expressions shot frontally (i.e., Visuomotor Priming effect), rather than scenes acted by professional actors.

5 | Experimental Chapter 2:

Surprise

Surprise is evoked by unexpected (schema-discrepant) events, and its intensity is determined by the degree of schema-discrepancy, whereas the novelty and valence of the events that elicit it are not likely to have an independent effect (for a review of theoretical and empirical research on surprise see Reisenzein et al., 2019).

Unexpected events cause an automatic disruption of ongoing mental processes, followed by a shift in attention and attentional binding to events. In most laboratory experiments on surprise, expectations were first induced and then disconfirmed. In the repetition-change paradigm, participants are first exposed to a series of basic homogeneous trials. In the subsequent "surprise test," one or more of the expectations are disconfirmed. This method has been shown to reliably induce surprise of at least moderate intensity in the vast majority of participants, as indicated by both self-reports and indirect behavioral indicators of surprise (Reisenzein et al., 2019). In particular, a physiological orientation response is observed, characterized by increased skin conductance, deceleration of heart rate, and pupil dilation. According to basic emotion theory, facial expression includes eyebrow raising, eye widening and mouth opening (Darwin, 1872; Reisenzein, 2000). However, the classic facial expression of surprise rarely occurs. Several studies (reviewed in Reisenzein et al., 2013), in fact, have found that eyebrow arching is shown by only a minority, about 10 percent in the repetition-change paradigm (Reisenzein et al., 2006) and about 30 percent in response to highly surprising items (Reisenzein, 2000; Schützwohl & Reisenzein, 2012). This indicates the possibility that the expression of surprise may simply require additional conditions to emerge reliably. With this idea in mind, I adopted the Emotional Contagion and Motor Contagion paradigms to thoroughly study the effect of different induction methods on the upper part of the face. For the Emotional Contagion paradigm (Experiment 1), I showed neutral videoclips of movies, and at the end, the experimenter revealed surprising information to participants (e.g., about the relationships between actors and directors in the movie). In Experiment 2, on the other hand, I showed videos of people shot frontally as they received unexpected news.

Experiment 1

Methods

Participants

Eight participants (6 females and 2 males) aged between 23 and 32 years ($Mean_{age}$=25.875, SD=2.997) were recruited. Twelve participants were in fact excluded due to drop out in the Posed condition (N=10) or technical/recording problems (N=2).

Stimuli and Procedure

For the Posed condition I adopted a static picture of surprise. Spontaneous surprise was instead elicited by using video clips inducing emotional contagion.

Results

Linear Mixed Effect Models: Posed vs. Spontaneous Proximal Movements

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of all the spatial and Acceleration parameters when the participants performed a posed expression of surprise, compared to when they were spontaneously surprised (DDCH: $F_{(1,7)}$=12.031, p=0.004, VS-MPR=17.512; MACH: $F_{(1,7)}$=5.117, p=0.040, VS-MPR=2.851; Figure 5.1 A-B). Moreover, the Maximum Distance was reached earlier when the expression was posed than when it was spontaneous (TMD%CH: $F_{(1,7)}$=9.961, p=0.007, VS-MPR=10.584; Figure 5.1 C). None of the other parameters revealed significant differences through conditions (all p_s > 0.05).

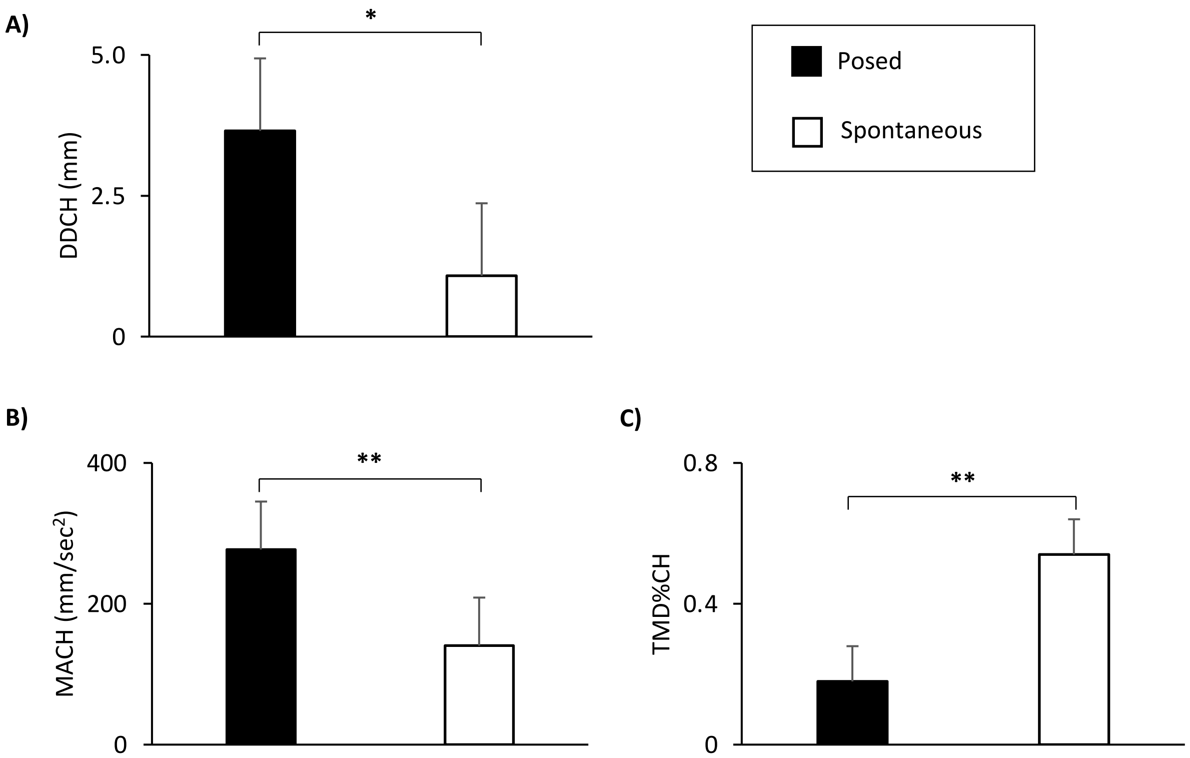

Figure 5.1. Graphical representation of spatial, speed, and temporal components of movement in the lower part (i.e., Cheilion markers) of the face during Posed and Spontaneous expressions of surprise. (A) Delta Distance (DDCH); (B) Maximum Acceleration (MACH); (C) Time to Maximum Distance (TMD%CH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01).

Upper part of the face – Eyebrows (EB)

Linear Mixed-Effect Models did not reveal a significant effect in the upper part of the face. The spatial, Velocity and temporal parameters were not statistically significant (all $p_s > 0.05$).

CORRELATIONS BETWEEN IRI AND KINEMATICS MEASURES

Correlations emerged between IRI measurements and spatial and temporal parameters, but only in the lower part of the face (i.e., Cheilion markers). In particular, negative correlation was found between DD and FS subscale for the Posed condition. Positive correlations emerged between TMD% and the subscales PT and FS. In the spontaneous condition, negative correlation was found between TMD and PT (Table 5.1).

Table 5.1. Pearson's Correlation between IRI and kinematic measure of posed and spontaneous expressions of surprise.

EXPRESSION	IRI		DD CH	MA CH	TMD% CH
Posed	COG	PT	-0.487	-0.349	**0.666***
		FS	**-0.653***	-0.444	**0.708***
	EMO	EC	-0.226	0.306	0.281
		PD	0.074	0.357	-0.040
Spontaneous	COG	PT	0.406	0.506	**-0.620***
		FS	0.120	0.193	-0.282
	EMO	EC	-0.176	0.180	-0.462
		PD	-0.353	-0.194	-0.102

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,7)}$=26.503, p=0.001, VS-MPR=41.854, η^2_p=0.791) was found. The amplitude was wider when the expression was posed than when it was spontaneous.

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,7)}$=16.360, p=0.005, VS-MPR=14.109, η^2_p=0.700) and a significant interaction Condition by Side of the Face ($F_{(1,7)}$=6.930, $p<0.05$, VS-MPR=3.214, η^2_p=0.497) were found. Post hoc comparisons revealed that the LeftCH during posed expression was more distal than the RightCH during spontaneous expression (2.474 mm and 0.584, $p<0.05$), and the RightCH during posed expression (3.176 mm) was more distal than the LeftCH during spontaneous expression (0.905 mm; $p<0.05$). Crucially, the RightCH was more distal during Posed (3.176 mm) than Spontaneous conditions (0.584 mm; $p<0.05$; see Figure 5.2 A).

Maximum Velocity (MV) | A significant main effect of the Condition ($F_{(1,7)}$=6.105, $p<0.05$, VS-MPR=2.728, η^2_p=0.466) was found. The peak Velocity was higher when the expression of surprise was posed than when it was spontaneous.

A significant main effect of Side of the face was found for MDec and TMDec% ($F_{(1,7)}$=6.505, $p<0.05$, VS-MPR=2.956, η^2_p=0.482; $F_{(1,7)}$=10.908, $p<0.05$, VS-MPR=6.489, η^2_p=0.609; see Figure 5.2 B-C). The Deceleration peak was higher and reached later in the Left than in the Right side of the face. Interaction with Condition was not significant, nor were the main effects or interactions of the other dependent measures significant (all $p_s > 0.05$).

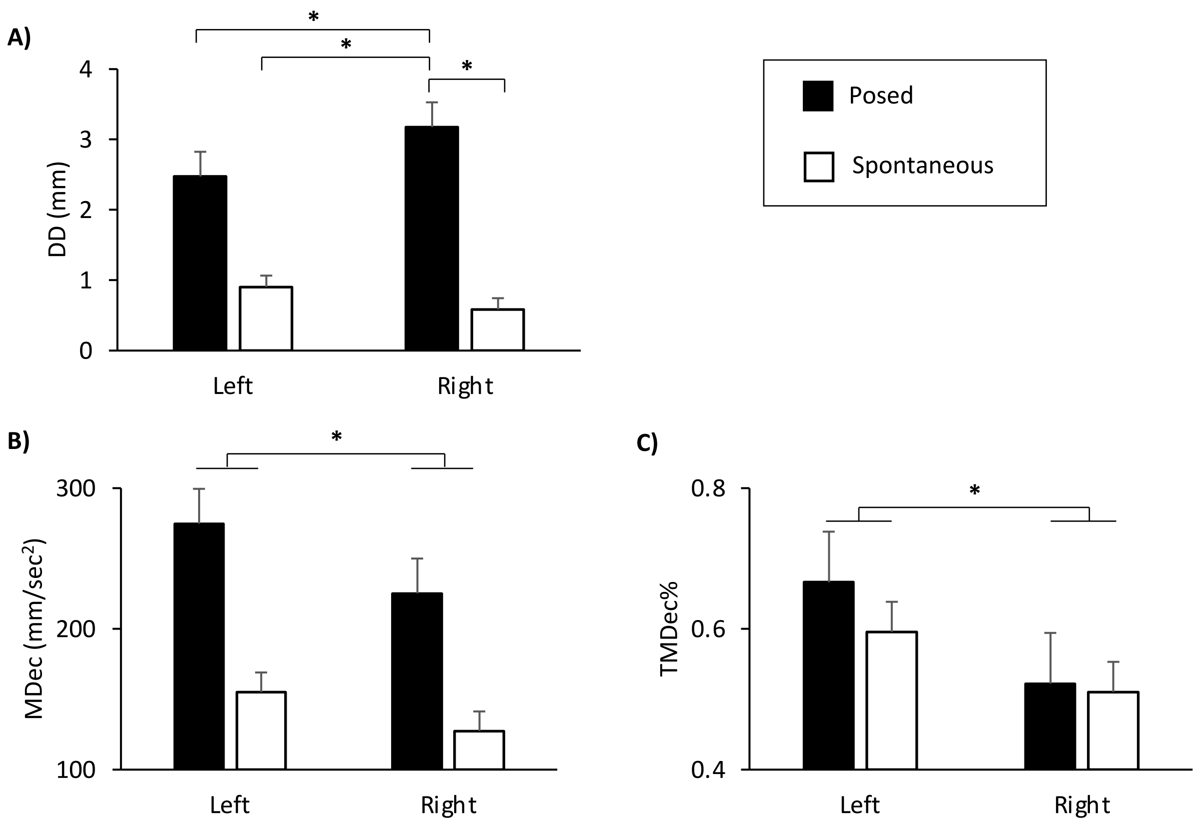

Figure 5.2. The interaction between Condition and Side of the face on Delta Distance (DD) is shown in panel (A). The main effect of the Side of the face on Maximum Deceleration (MDec) and on Time to Maximum Deceleration (TMDec%) is shown in panels (B) and (C), respectively. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05).

The upper part of the face – eyebrows

Repeated-measures ANOVA on the movement of each Eyebrow from the Tip of the nose revealed no significant main effect of the condition or side of the face (all $p_s > 0.05$).

Interim Discussion – Experiment 1

Proximal movements

The posed expressions of surprise were characterised by a larger Delta Distance and peak of Acceleration of the mouth corners than the spontaneous expressions. In temporal terms, the posed expressions showed an earlier peak Distance between the corners of the mouth. No statistically-significant variable was found in the upper part of the face.

IRI

Strong correlations ($r \geq 0.6$) between statistically significant parameters for the expressions of surprise in Experiment 1 and the IRI questionnaire were found only in the lower part of the face and only for the Cognitive scale. In particular, for the Posed condition, there was both a negative correlation between the Delta Distance and the FS subscale, and a positive correlation between this subscale and the percentage of time to Maximum Distance. Another positive correlation was also found between this parameter and the PT subscale. Notably, the opposite occurred for the Spontaneous condition: a negative correlation was observed between this parameter and the PT subscale.

Distal movements

The posed expressions of surprise were characterised by an earlier peak Distance between the corners of the mouth and the tip of the nose and a higher peak Velocity than the spontaneous expressions. In terms of lateralization, the Right corner of the mouth for the Posed condition was more distal (i.e., away from the tip of the nose) than for the Spontaneous condition. And the peak Deceleration was higher and more delayed in the LeftCH compared to the RightCH.

Emotional Contagion

The results on spatial and speed parameters of expressions of surprise confirmed the findings from a recent study which adopted 2-D motion analysis and a between-subjects design (Namba et al., 2021). In this thesis, by using three-dimensional motion analysis techniques, an Emotional Contagion paradigm and a within-subjects experimental design, I also found an effect on temporal parameters: an earlier peak Distance between the corners of the mouth for the Posed compared to the Spontaneous condition and a greater and more delayed Deceleration peak for LeftCH than for RightCH.

In lateralized terms, it seems that compared with the felt surprise, the on-demand expression involves a greater distal movement of the Right corner of the mouth.

Notably, no statistically-significant variable was found in the upper part of the face with the Emotional Contagion paradigm, thus confirming previous literature. Indeed, several studies (reviewed in Reisenzein et al., 2013) have found that eyebrow arching is shown by only a minority of persons (10-30%).

EXPERIMENT 2

METHODS

Participants

Seventeen participants (12 females and 5 males) aged between 20 and 29 years ($Mean_{age}$=23.412, SD=2.476) were recruited. Three participants were subsequently excluded due to poor registration for face tracking.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous surprise was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 38 healthy volunteers (27 females, 11 males; age=18-60 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods). The surprise scores of each video clip were significantly higher than the midpoint of the scale (all p_s<0.05) and I selected the three video clips with the highest scores on the Likert and the SAM arousal.

Results

Linear Mixed Effect Models: Posed vs. Spontaneous Proximal Movements

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with a decrease of the spatial and speed parameters when the participants performed a posed expression of surprise, compared to when they were spontaneously surprised (MDCH: $F_{(1,16)}=34.460$, $p<0.001$, VS-MPR=1457.749; DDCH: $F_{(1,16)}=4.359$, $p=0.045$, VS-MPR=2.642; MVCH: $F_{(1,16)}=8.916$, $p=0.005$, VS-MPR=13.080; Figure 5.3 A-C). In addition, Maximum Distance and Velocity were reached earlier during posed expressions than spontaneous (TMD%CH: $F_{(1,16)}=36.869$, $p<0.001$, VS-MPR=29938.037; TMV%CH: $F_{(1,16)}=31.888$, $p<0.001$, VS-MPR=9574.236; Figure 5.3 D-E).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of all the spatial and speed parameters when the participants performed a posed expression of surprise, compared to when they were spontaneously surprised (MDEB: $F_{(1,16)}=11.258$, $p=0.004$, VS-MPR=16.583; DDEB: $F_{(1,16)}=18.540$, $p<0.001$, VS-MPR=89.955; MVEB: $F_{(1,16)}=16.465$, $p<0.001$, VS-MPR=152.172; Figure 5.3 F-H). None of the other parameters revealed significant differences through conditions (all $p_s > 0.05$).

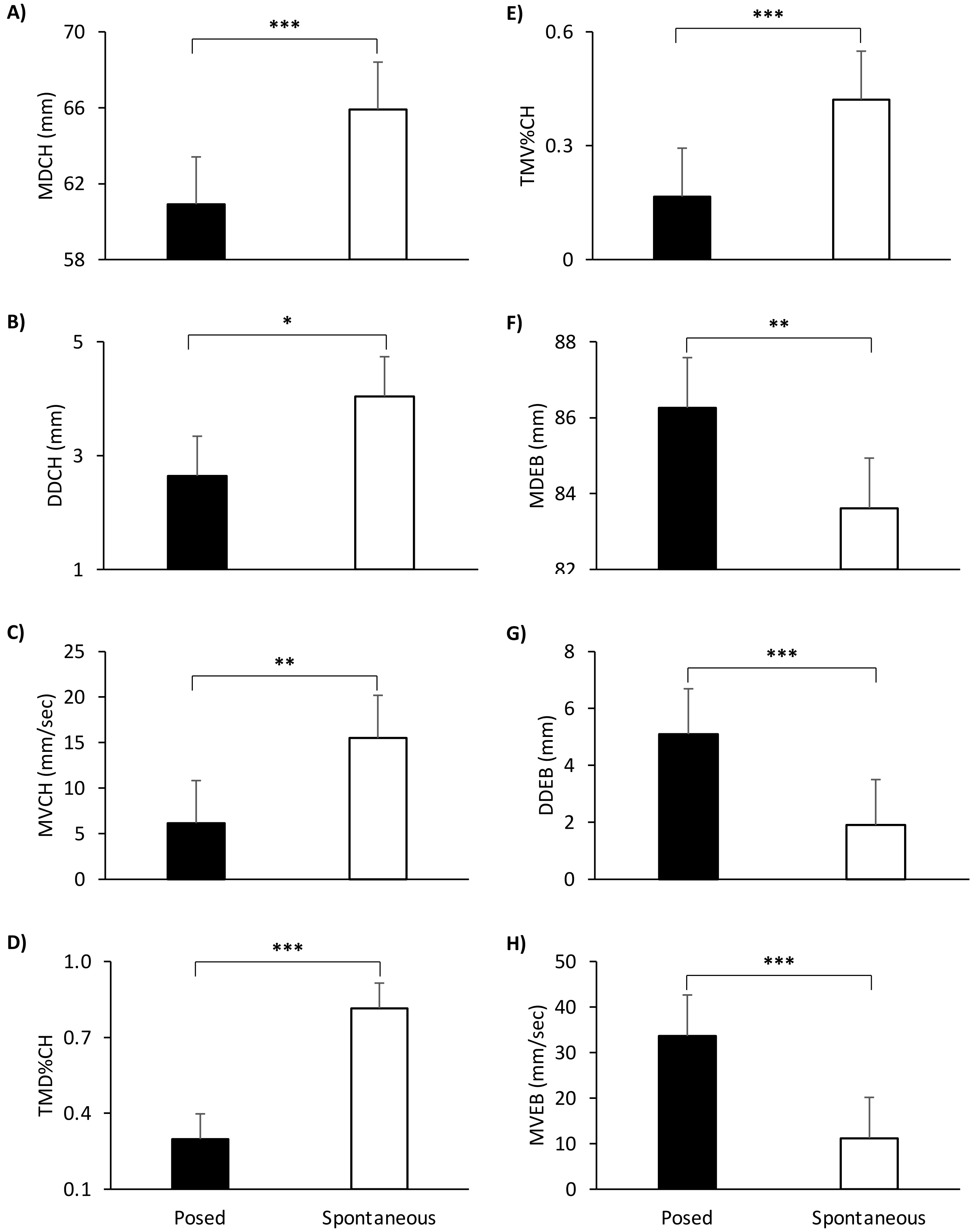

Figure 5.3. Graphical representation of spatial, speed, and temporal components of movement in the lower part (i.e., Cheilion markers) and upper part (i.e., Eyebrows) of the face during Posed and Spontaneous expressions of surprise. (A) Maximum Distance (MDCH); (B) Delta Distance (DDCH); (C) Maximum Velocity (MVCH); (D) Time to Maximum Distance (TMD%CH); (E) Time to Maximum Velocity (TMV%CH); (F) Maximum Distance (MDEB); (G) Delta Distance (DDEB); (H) Maximum Velocity (MVEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01; ***=p<0.001).

Correlations between IRI and kinematics measures

Positive correlations emerged on temporal parameter of the lower part of the face (i.e., Cheilion markers). In particular, for the spontaneous condition I found a positive correlation between IRI emotional subscales and TMD%CH (EC: r=0.575 and PD: r=0.591).

Table 5.2. Pearson's Correlation between IRI and kinematic measure of posed and spontaneous expressions of surprise.

EXPRESSION	IRI		MD CH	DD CH	MV CH	TMD% CH	TMV% CH	MD EB	DD EB	MV EB
Posed	COG	PT	0.205	0.232	0.443	0.226	0.266	0.204	0.163	0.355
		FS	0.098	-0.311	0.188	-0.012	0.058	0.125	0.163	0.452
	EMO	EC	-0.053	-0.322	-0.262	-0.304	-0.014	-0.227	-0.411	0.032
		PD	0.070	-0.068	0.076	-0.070	0.229	0.211	0.111	0.437
Spontaneous	COG	PT	0.376	0.086	0.060	0.128	0.118	-0.010	0.189	0.084
		FS	0.422	0.108	0.204	0.421	0.352	0.128	-0.516	-0.362
	EMO	EC	0.448	0.242	0.302	**0.575***	0.539	-0.399	-0.275	-0.424
		PD	0.265	0.142	0.159	**0.591***	0.157	-0.086	-0.226	-0.382

REPEATED-MEASURES ANOVA: POSED VS. SPONTANEOUS DISTAL MOVEMENTS

Lower part of the face – Cheilions (CH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,15)}$=17.679, p<0.001, VS-MPR=66.958, η^2_p=0.541) was found. The amplitude of the mouth was wider when the expression was posed than when it was spontaneous (61.798 and 59.956 mm, respectively).

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,15)}$=19.185, p=0.003, VS-MPR=19.185, η^2_p=0.470) was found. The amplitude range of the mouth was wider when the expression was posed than when it was spontaneous (2.881 and 1.559 mm, respectively).

Maximum Velocity (MV) | Two significant main effects of the Condition ($F_{(1,15)}$=6.261, p=0.024, VS-MPR=4.061, η^2_p=0.294) and Side of the face ($F_{(1,15)}$=5.369, p=0.035, VS-MPR=3.133, η^2_p=0.264) were found. The peak Velocity was higher when the expression of surprise was posed than when it was spontaneous (14.913 mm/sec and 8.573 mm/sec, respectively). In addition, this peak was higher in the Left side of the face than in the Right (11.103 and 12.383 mm/sec, respectively; Figure 5.4 A).

Maximum Deceleration (MDec) | Two significant main effects of the Condition ($F_{(1,15)}$=11.828, p=0.004, VS-MPR=17.950, η^2_p=0.441) and Side of the face ($F_{(1,15)}$=9.934, p=0.007, VS-MPR=11.125, η^2_p=0.398) were found. The Deceleration peak was higher when the expression of surprise was posed than when it was spontaneous (259.064 and 181.523 mm/sec^2, respectively). In addition, this peak was higher in the Left side of the face than in the Right side (203.746 and 236.841 mm/sec^2, respectively; Figure 5.4 B).

Time to Maximum Distance (TMD%) | A significant main effect of the Condition ($F_{(1,15)}$=14.322, p=0.002, VS-MPR=26.585, η^2_p=0.524) was found. The Maximum Distance of the corners of the mouth was reached later when the expression was posed than spontaneous (89.9 and 67.3 %, respectively).

Time to Maximum Deceleration (TMDec%) | A significant main effect of the Side of the face ($F_{(1,15)}$=18.219, p<0.001, VS-MPR=74.806, η^2_p=0.548) was found. The peak of Deceleration was reached later in the Left side of the face than in the Right (57.3 and 45.1 %, respectively; Figure 5.4 C).

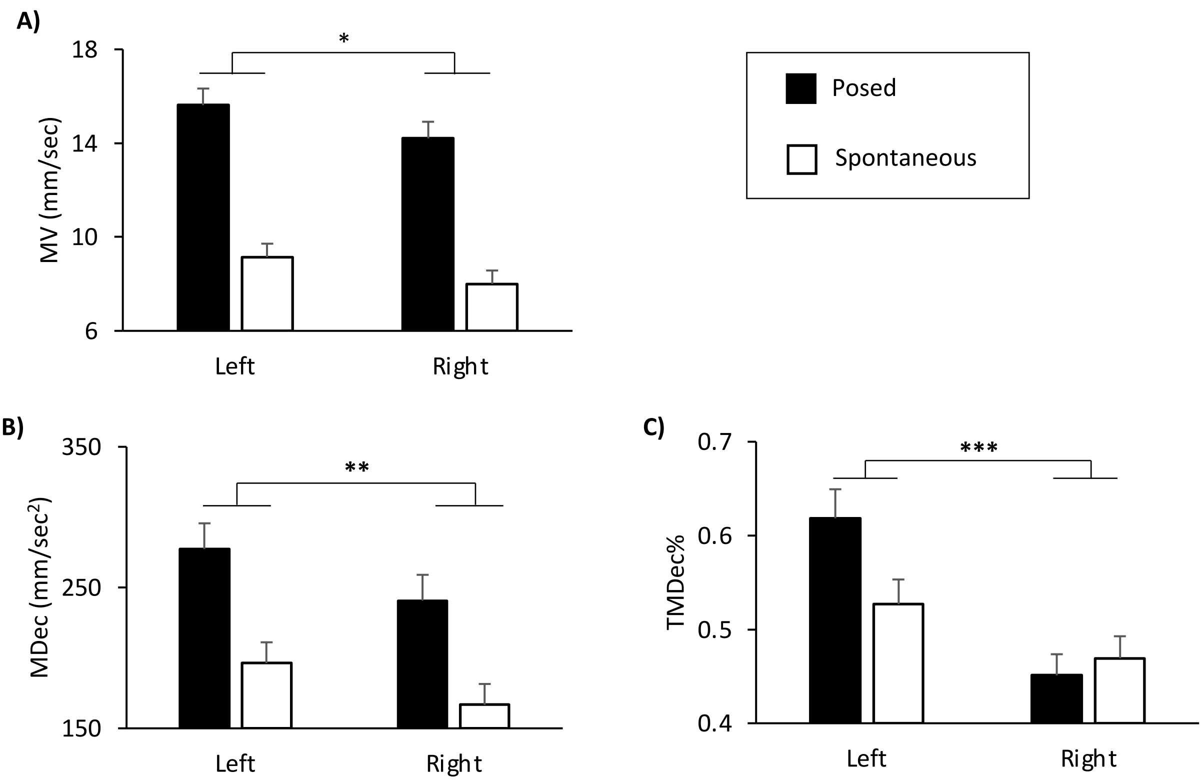

Figure 5.4. The graphs show: (A) Maximum Velocity (MV), (B) Maximum Deceleration (MDec), and (C) Time to Maximum Deceleration reached by the Left and Right Cheilions occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01; ***=p<0.001).

Upper part of the face – Eyebrows (EB)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,15)}$=37.801, p<0.001, VS-MPR=1812.204, η^2_p=0.716) was found. The amplitude was wider when the expression was posed than when it was spontaneous (83.816 and 78.661 mm, respectively).

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,15)}$=76.488, p<0.001, VS-MPR=86343.060, η^2_p=0.836) was found. The amplitude range was wider when the expression was posed than when it was spontaneous (5.945 and 1.229 mm, respectively).

Maximum Velocity (MV) | A significant main effect of the Condition ($F_{(1,15)}$=69.961, p<0.001, VS-MPR=27864.593, η^2_p=0.808) was found. The peak Velocity was higher when the expression of surprise was posed than when it was spontaneous (45.073 and 9.898 mm/sec, respectively).

Time to Maximum Distance (TMD%) | A significant main effect of the Condition ($F_{(1,15)}$=7.021, p=0.018, VS-MPR=5.045, η^2_p=0.319) was found. The Maximum Distance was reached later when the expression was posed than when it was spontaneous (85 and 60.4 %, respectively).

Time to Maximum Velocity (TMV%) | A significant main effect of the Condition ($F_{(1,15)}$=5.024, p=0.041, VS-MPR=2.831, η^2_p=0.251) was found. The peak of speed was reached later when the expression was posed than when it was spontaneous (67.4 and 47 %, respectively).

Interim Discussion – Experiment 2

Proximal movements

In Experiment 2, I found an opposite trend compared to Experiment 1. In particular, the peak Distance of the corners of the mouth, Delta, and Velocity were greater for the Spontaneous than for the Posed condition. In temporal terms, instead, the trend observed for all the other expressions of emotion was confirmed: the maximum mouth Distance and peak Velocities were reached earlier for posed than for spontaneous expressions. For the upper part of the face: posed expressions showed larger values for peak Distance, Delta, and Velocity.

IRI

Strong correlations ($r \geq 0.6$) between statistically significant parameters for the expressions of surprise in Experiment 2 and the IRI questionnaire were found only in the lower part of the face and only for the Emotional scale. In particular, for the Spontaneous condition, there were two positive correlations between the percentage of time at which the Maximum Distance occurred and both the Empathic Concern and Personal Distress subscales.

Distal movements

The posed expressions showed a larger peak Distance (absolute value and Delta) between the corners of the mouth and the tip of the nose compared to the spontaneous expressions. In terms of speed, I observed higher Velocity peaks for the posed expressions than for the spontaneous ones and for the Left side of the face than for the Right side. In terms of time, the Maximum Distance was delayed for posed compared to spontaneous expressions. The Maximum Deceleration was higher and delayed in the Left compared to the Right side of the face. In the upper part of the face, the posed expressions showed larger peaks of the Maximum Distance (absolute value and Delta) and Velocity between the eyebrows and the tip of the nose compared to the spontaneous expressions. In terms of time, Maximum eyebrow Distance and Maximum Deceleration time were delayed for posed expressions compared to spontaneous ones.

Motor Contagion

These results on spatial and speed parameters support recent findings on posed surprise (Namba et al., 2021). Here, in addition, I found a stable effect on temporal parameters: the peak Distance between the corners of the mouth and their peak Velocity were reached earlier for posed than for spontaneous expressions. In terms of distal movements, the peak Distance was delayed for posed compared to spontaneous expressions and the peak Deceleration was delayed in the Left compared to the Right side of the face. In the upper part of the face as well, peak Distance and Deceleration were delayed for posed compared to spontaneous expressions.

Notably, statistically-significant spatial, speed and temporal parameters were found in the upper part of the face when the Motor Contagion paradigm was adopted, thus suggesting the crucial role of the induction method when trying to find consistencies across studies in the expression of surprise (Reisenzein et al., 2013).

Another important thing to note, the expressions of surprise made upon request showed the corners of the mouth moving closer together and at the same time moving away from the nose, indicating a movement in a downward direction. This finding reminds us how posed expressions follow prototypical patterns of reference, far from the reality of authentic expressions.

Comparison analysis – Experiment 1 vs. 2

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Maximum Distance (MDCH) | A significant main effect of Condition was found ($F_{(1,23)}$=12.367, p=0.001, VS-MPR=31.582, η^2_p=0.350). Spontaneous expressions were wider than posed expressions (62.700 and 60.237 mm, respectively). The interaction between Experiment and Condition was also statistically significant ($F_{(1,23)}$=13.065, p=0.001, VS-MPR=38.660, η^2_p=0.362). Post hoc comparisons revealed that spontaneous expressions of surprise performed in Experiment 2 showed a wider Distance than posed expression (p<0.001). Moreover, spontaneous expressions in Experiment 2 had a wider Distance than both posed (p=0.008) and spontaneous expression (p=0.007) in Experiment 1 (Figure 5.5 A).

Delta Distance (DDCH) | The interaction between Experiment and Condition was statistically significant ($F_{(1,23)}$=10.063, p=0.004, VS-MPR=15.845, η^2_p=0.304). Post hoc comparisons revealed that spontaneous expression of surprise performed in Experiment 2 showed a wider Distance than spontaneous expression performed in Experiment 1 (p=0.003) (Figure 5.5 B).

Maximum Velocity (MVCH) | A significant main effect of Condition was found ($F_{(1,23)}$=4.456, p=0.046, VS-MPR=2.206, η^2_p=0.162). The peak speed was higher for spontaneous than posed expressions (10.843 and 5.228 mm/sec, respectively).

Maximum Acceleration (MACH) | A significant main effect of Condition was found ($F_{(1,23)}$=4.329, p=0.049, VS-MPR=2.497, η^2_p=0.158). The Acceleration peak was higher for posed than spontaneous expressions (247.648 and 168.191 mm/sec^2, respectively).

Time to Maximum Distance (TMD%CH) | A significant main effect of Condition was found ($F_{(1,23)}$=24.462, p<0.001, VS-MPR=700.952, η^2_p=0.515). The Maximum Distance was reached earlier during posed than spontaneous expressions.

Time to Maximum Velocity (TMV%CH) | The interaction between Experiment and Condition was statistically significant ($F_{(1,23)}$=4.687, p=0.041, VS-MPR=2.808, η^2_p=0.169). Post hoc comparisons revealed that in Experiment 2, spontaneous expression of surprise showed a wider Distance than posed expressions (p=0.041) (Figure 5.5 C).

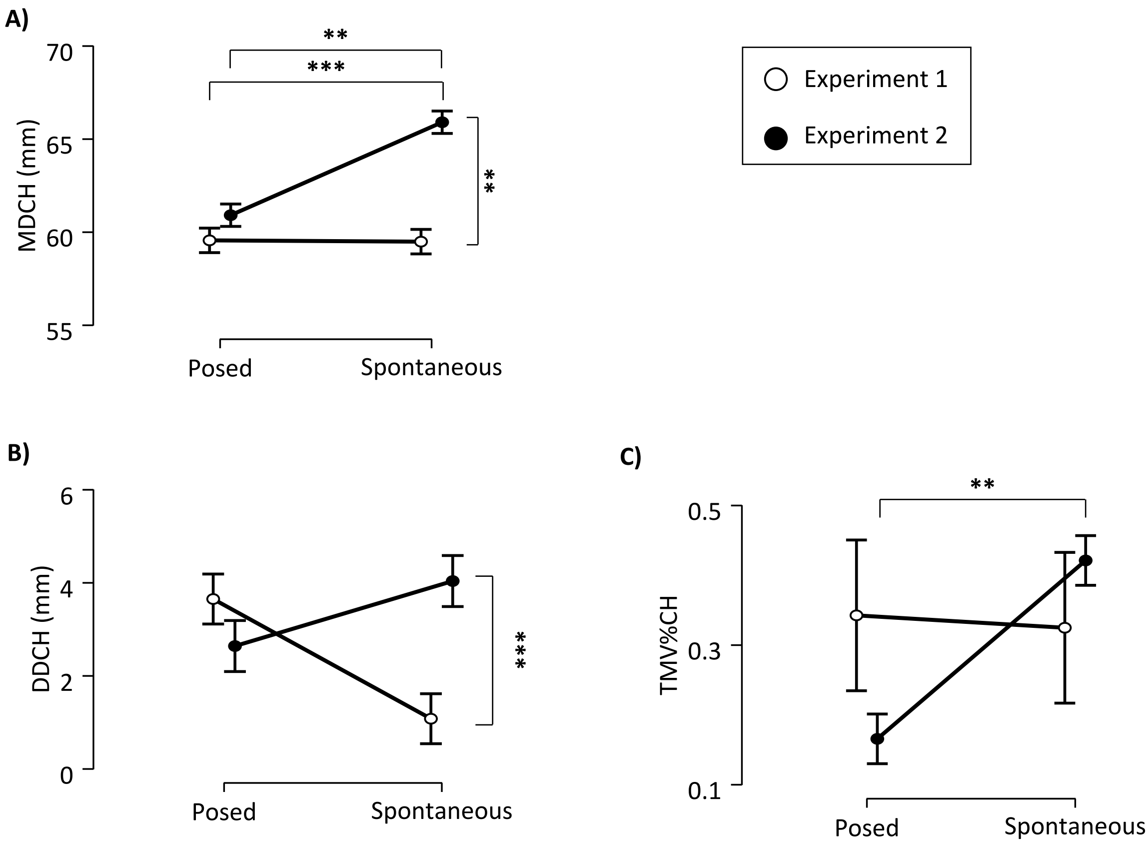

Figure 5.5 Graphical representation of spatial and time components of movement in the lower part part of the face during Posed and Spontaneous expressions of surprise in Experiments 1 and 2. (A) the Maximum Distance (MDCH), (B) Delta Distance (DDCH), and (C) time to Maximum Velocity (TMD%CH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**= p<0.01; ***= p<0.001).

Upper part of the face – Eyebrows (EB)

Maximum Distance (MDEB) | A significant main effect of Condition was found ($F_{(1, 23)}$=8.192, p=0.009, VS-MPR=8.824, η^2_p=0.263). Posed expressions were wider than spontaneous expressions (81.813 and 79.954 mm, respectively).

Delta Distance (DDEB) | A significant main effect of Condition was found ($F_{(1, 23)}$=6.894, p=0.015, VS-MPR=5.805, η^2_p=0.231). Posed expressions were wider than spontaneous (4.151 and 2.543 mm, respectively). The interaction between Experiment and Condition was statistically significant

($F_{(1,23)}$=6.661, p=0.017, VS-MPR=5.381, η^2_p=0.225). Post hoc comparisons revealed that, in Experiment 2, posed expression of surprise showed a wider Delta than spontaneous expression (p<0.001; Figure 5.6 A).

Maximum Velocity (MVEB) | A significant main effect of Condition was found ($F_{(1, 23)}$=4.196, p=0.05, VS-MPR=2.390, η^2_p=0.154). The peak speed was higher for posed than spontaneous expressions (26.052 and 16.868 mm/sec, respectively). The interaction between Experiment and Condition was statistically significant ($F_{(1,23)}$=8.800, p=0.007, VS-MPR=10.700, η^2_p=0.277). Post hoc comparisons revealed that, in Experiment 2, posed expression of surprise showed a higher peak Velocity than spontaneous expression (p<0.001; Figure 5.6 B).

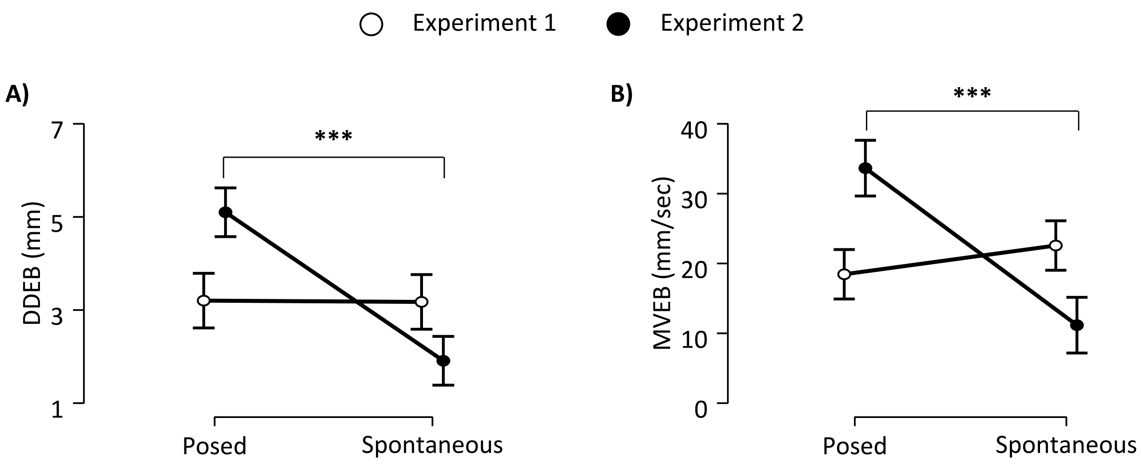

Figure 5.6. Graphical representation of spatial and speed components of movement in the upper part of the face during Posed and Spontaneous expressions of surprise in Experiments 1 and 2. (A) Delta Distance (DDEB) and (B) Maximum Velocity (MVEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (***=p<0.001).

MIXED ANOVA: DISTAL MOVEMENTS

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | The main effect of Condition was significant ($F_{(1,23)}$=33.592, p<0.001, VS-MPR=4653.079, η^2_p=0.594). Posed expressions showed an increased mouth widening than spontaneous expressions (61.293 and 58.788 mm, respectively).

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,23)}$=28.551, p<0.001, VS-MPR=1495.531, η^2_p=0.565). Posed expressions showed an increased range of mouth widening than spontaneous expressions (2.783 and 1.280 mm, respectively).

Maximum Velocity (MV) | The main effect of Condition was significant ($F_{(1,23)}$=12.229, p=0.002, VS-MPR=30.337, η^2_p=0.347). Posed expressions had a higher peak Velocity during posed than spontaneous expression of surprise (15.096 and 7.899, respectively). The main effect of Side of the face was also significant ($F_{(1,23)}$=12.490, p=0.002, VS-MPR=35.735, η^2_p=0.352). Expressions had a higher peak Velocity in the Left side of the face than in the Right side (12.214 and 10.780 mm/sec, respectively).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1,23)}$=6.355, p=0.019, VS-MPR=4.867, η^2_p=0.216). Posed expressions had a higher peak Acceleration than spontaneous expressions of surprise (236.249 and 170.334 mm/sec^2, respectively).

Maximum Deceleration (MDec) | The main effect of Condition was significant ($F_{(1,23)}$=7.073, p=0.014, VS-MPR=6.154, η^2_p=0.235). Posed expressions had a higher peak Deceleration during posed than spontaneous expression of surprise (248.558 and 172.971 mm/sec^2, respectively). The main effect of Side of the face was also significant ($F_{(1,23)}$=11.938, p=0.002, VS-MPR=27.852, η^2_p=0.342). Expressions had higher peaks of Deceleration in the Left side of the face than in the Right side (226.449 and 195.080 mm/sec^2, respectively).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Maximum Distance (MD) | The main effect of Condition was significant ($F_{(1,23)}$=17.262, p<0.001, VS-MPR=122.134, η^2_p=0.429). Eyebrows were more distal for posed than for spontaneous expressions (82.702 and 78.904 mm, respectively). The 2-way interactions between Condition and Experiment was significant ($F_{(1,23)}$=8.326, p=0.008, VS-MPR=9.208, η^2_p=0.266). Post hoc comparisons revealed that spontaneous expressions of surprise performed in Experiment 2 showed a smaller amplitude than posed expressions (p<0.001; Figure 5.7 A).

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,23)}$=19.419, p<0.001, VS-MPR=211.933, η^2_p=0.458). The 2-way interactions between Condition and Experiment was significant ($F_{(1,23)}$=15.134, p<0.001, VS-MPR=69.082, η^2_p=0.397). Post hoc comparisons revealed that spontaneous expressions of surprise performed in Experiment 2 showed a smaller amplitude than posed expressions in both Experiment 1 and Experiment 2 (all p_s<0.05; Figure 5.7 B).

Maximum Velocity (MV) | The main effect of Condition was significant ($F_{(1,23)}$=11.898, p=0.002, VS-MPR=27.527, η^2_p=0.341). The 2-way interactions between Condition and Experiment was also significant ($F_{(1,23)}$=25.490, p<0.001, VS-MPR=881.687, η^2_p=0.526). Post hoc comparisons revealed that spontaneous expressions of surprise performed in Experiment 1 showed a higher peak Velocity than in Experiment 2. Moreover, spontaneous expressions of surprise performed in Experiment 2 showed a lower peak Velocity than posed expressions (all p_s<0.01; Figure 5.7 C).

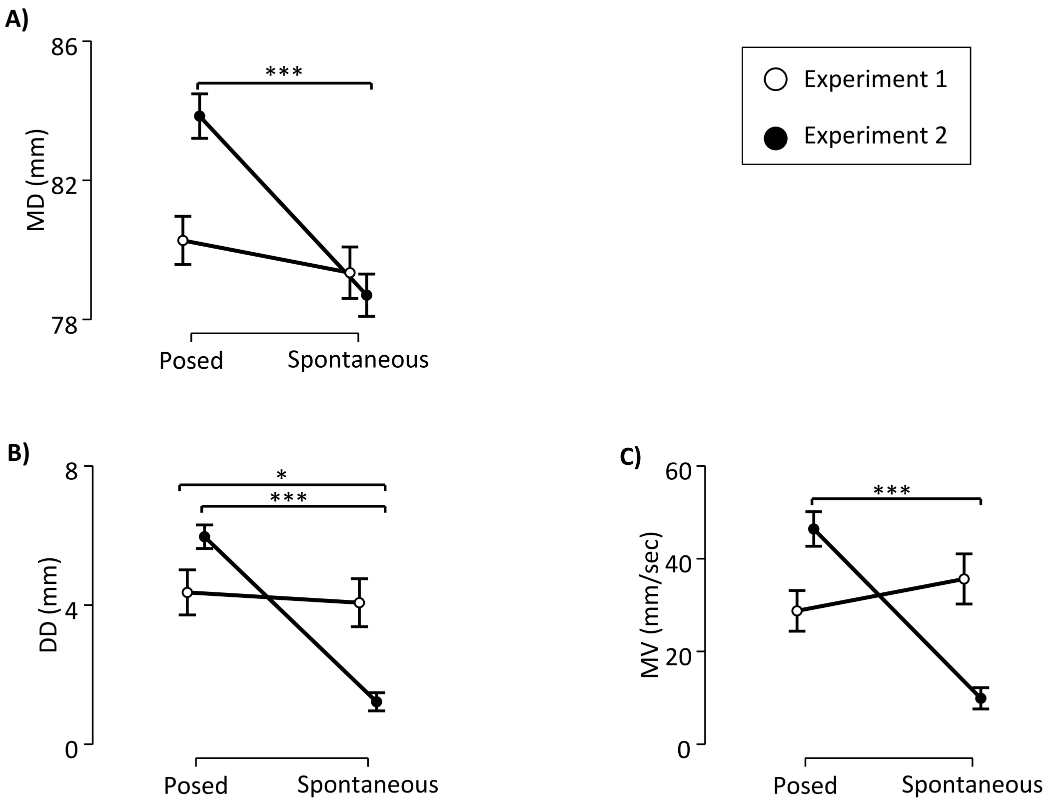

Figure 5.7. Graphical representation of spatial and speed parameters of movement in the upper part of the face during Posed and Spontaneous expressions of surprise in Experiments 1 and 2: (A) Maximum Distance (MD), (B) Delta Deceleration (DD), and Maximum Velocity (MV). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01; ***=p<0.001).

Interim Discussion – Comparison Analysis

Proximal movements

Mixed ANOVA on the two experiments showed that Motor Contagion (Experiment 2) specifically influenced both the spatial and temporal parameters of mouth movement. In particular, the spatial parameters (i.e., MDCH, DDCH) differed as a function of the mode of induction, so that a spontaneous expression was larger after observing expressions of surprise filmed frontally than when it was preceded by surprising scenes (i.e., Emotional Contagion).

Distal movements

A wide main effect of the Condition (Posed vs. Spontaneous) in terms of space, time and speed was observed in both Experiments. Taking the hemiface into consideration, two main effects of the Side of the face emerged for the speed parameters: expressions of surprise had greater peak Velocity and Deceleration in the Left compared to the Right side of the mouth. An interesting effect also emerged in spontaneous expressions: when they were induced by Emotional Contagion (Exp1), they were characterized by a quicker displacement of the Eyebrows compared to Experiment 2.

Emotional vs. Motor Contagion

According to the Emotion Type Hypothesis developed by Ross and colleagues (1994, 2019), the right hemisphere would mainly control primary emotions such as surprise. In this research, the peak Velocity and Deceleration were, in fact, greater on the Left Side of the mouth, mediated by the right hemisphere.

When comparing the effect of the two methods of induction on spontaneous expressions, a supremacy of the Emotional Contagion was shown in the lower part of the face, whereas a supremacy of the Motor Contagion was evident in the upper part of the face. As I said before, the influence of the induction method might be the key to reconcile different hypotheses on facial expressions.

6 | Experimental Chapter 3:

Disgust

Disgust is often considered the most visceral of all basic emotions (Harrison et al., 2010), as it elicits peripheral bodily changes that facilitate the body's protection from contaminating objects (Chapman & Anderson, 2012; Curtis, 2011): in particular, potentially harmful (e.g. decomposed) food (Rozin & Fallon, 1987).

Disgust has traditionally been regarded as a trigger for the avoidance response, as it has the function of signalling behaviours that must be avoided (Rozin et al., 1999, 2008; Tybur et al., 2013). From this point of view, a disgusted face could have the function of increasing vigilance to detect the source of a potential threat in the environment. According to the FACS method, the central components of the disgust expression are raising of the upper lip, nose wrinkling and eyebrows pulled down (Ekman et al., 2002).

In a pioneering experiment published in Nature, Phillips and colleagues (1997) used functional magnetic resonance imaging (fMRI) to examine the neural substrate of the perception of disgust expressions. They were the first to demonstrate that both strong and mild expressions of disgust activate the anterior insular cortex.

The anterior insula has been identified in primates as the gustatory cortex (Rolls et al., 1994), containing neurons that respond to pleasant and unpleasant tastes (Yaxley et al., 1988). In humans, activation of the anterior insula has been demonstrated during salt tasting (Kinomura et al., 1994), perception of aversive stimuli such as pain and perception of facial expressions of disgust. Taken together, these studies suggest that the neural response to others' facial expressions of disgust is linked to brain regions involved in the perception of unpleasant tastes. This suggests that our responses to others' disgust, perhaps through associative learning between visual stimuli and taste (Rolls et al., 1996), have become closely linked to the evaluation of unpleasant stimuli.

Although this emotion has a well-defined neural substrate and a long evolutionary history (Darwin, 1872), numerous studies have shown low to moderate inter-individual correlations between self-reports and facial expressions (e.g., 0.37–0.55, Ekman et al., 1980) and sometimes non-significant correlations (e.g., $r < 0.20$, Jäncke & Kaufmann, 1994). As for the expressions of surprise, I adopted the Emotional Contagion and Motor Contagion paradigms to thoroughly study the effect of different induction methods on the lower and upper facial expressions. For the Emotional Contagion paradigm (Experiment 1), in particular, I showed videoclips of movies showing disgusting pimples being squeezed and a man cutting calluses from his foot with a knife. In Experiment 2, on the other hand, I showed videos of people shot frontally as they were disgusted by what they were eating (e.g., live octopus and beetle larva).

EXPERIMENT 1

METHODS

Participants

Fourteen participants (10 females and 4 males) aged between 21 and 32 years ($Mean_{age}$=24.381, SD=2.439) were recruited. Six participants were subsequently excluded due to poor registration for face tracking (N=5) or technical/recording problems (N=1).

Stimuli and Procedure

For the Posed condition I adopted a static picture of disgust. Spontaneous disgust was instead elicited by using video clips inducing emotional contagion.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with a decrease of the spatial parameter when the participants performed a posed expression of disgust, compared to when they performed the same expression spontaneously (MD: $F_{(1,13)}$=9.112, p=0.01, VS-MPR=8.065; Figure 6.1). None of the temporal and Velocity parameters revealed significant differences through conditions (all $p_s > 0.05$).

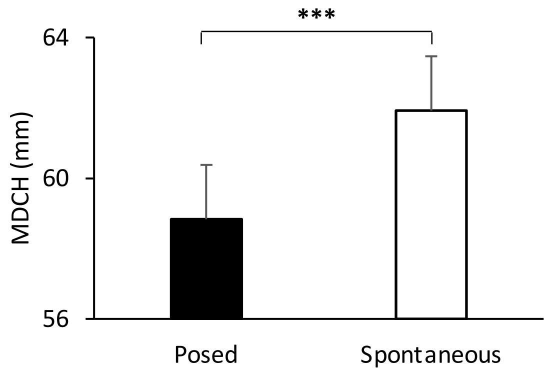

Figure 6.1. Graphical representation of Maximum Distance (MDCH) of movement in the lower part (i.e., Cheilion markers) of the face during Posed and Spontaneous expressions of disgust. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (***=p<0.001).

Upper part of the face – Eyebrows (EB)

Linear Mixed-Effect Models did not reveal a significant effect in the upper part of the face. The spatial, Velocity and temporal parameters were not statistically significant (all $p_s > 0.05$).

Correlations between IRI and kinematics measures

No significant correlations emerged between the IRI subscales and the Maximum Distance reached from the corners of the mouth (Table 6.1).

Table 6.1. Pearson's Correlation between IRI and kinematic measure of posed and spontaneous expressions of disgust.

EXPRESSION	IRI		MD CH
Posed	COG	PT	0.354
		FS	0.153
	EMO	EC	0.288
		PD	-0.262

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

A repeated-measures ANOVA on the movements of each Left and Right Cheilion from the Tip of the Nose during Posed and Spontaneous conditions was run. The analysis did not reveal a significant main effect of the Condition (all $p_s > 0.05$). A significant main effect of Side of the face was found for TMD% ($F_{(1,11)}=6.905$, $p=0.024$, VS-MPR=4.176, $\eta^2_p=0.386$). The Maximum Distance was reached earlier in the Left than in the Right side of the face (Figure 6.2 A). Interaction with Side of the face was not significant, nor were the main effects or interactions of the other dependent measures significant (all $p_s > 0.05$).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

The repeated-measures ANOVA on the movement of each Eyebrow from the Tip of the Nose did not reveal a significant main effect of the Condition (all $p_s > 0.05$). Significant main effect of Side of the face was found for MD, DD, TMA%. This movement reached a wider amplitude and earlier Acceleration peak in the Left side of the face (MD: $F_{(1,13)}=19.873$, $p<0.001$, VS-MPR=77.624, $\eta^2_p=0.605$; DD: $F_{(1,13)}=8.781$, $p=0.011$, VS-MPR=7.422, $\eta^2_p=0.403$; TMA%: $F_{(1,13)}=4.814$, $p=0.047$, VS-MPR=2.560, $\eta^2_p=0.270$; Figure 6.2 B-D).

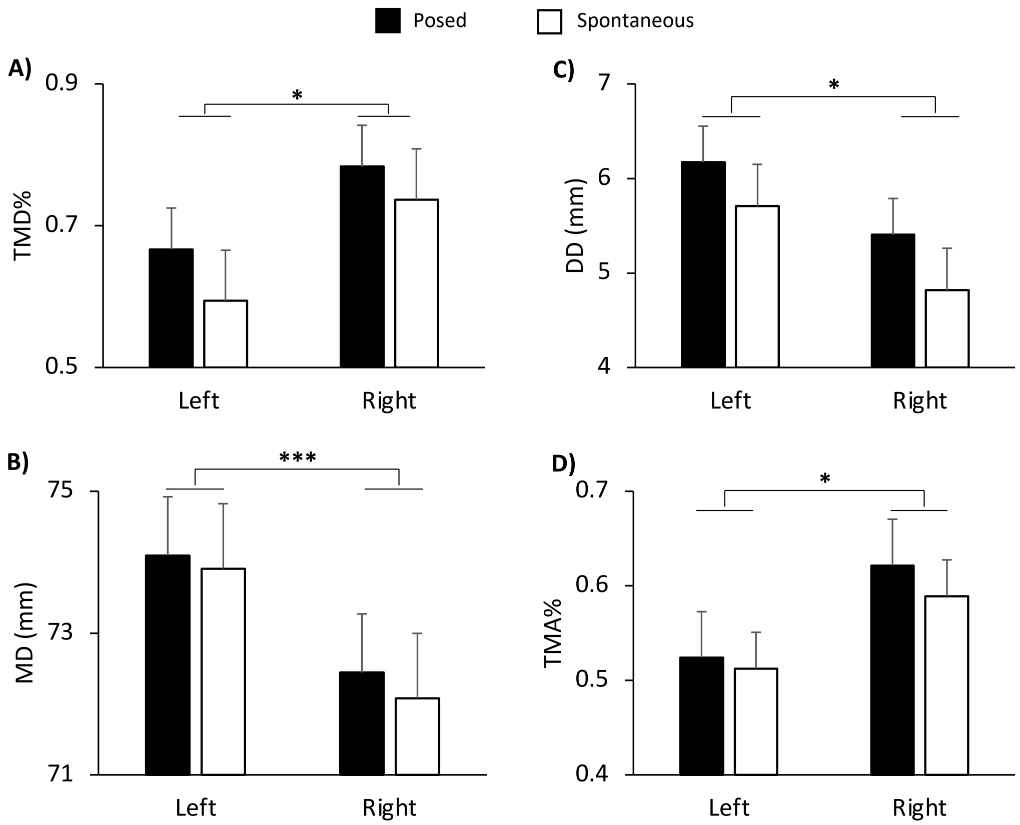

Figure 6.2. The Time to Maximum Distance reached by the Left and Right Cheilions occur across conditions (TMD%) is shown in panel (A). The Maximum Distance (MD); Delta Distance (DD); the percentage of Time at which the Acceleration peak is reached (TMA%) relative to the Left and Right eyebrows are shown in panels (B), (C), and (D), respectively. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; ***= p<0.001).

INTERIM DISCUSSION – EXPERIMENT 1

Proximal movements

The results of the Linear mixed-effects models indicate that spontaneous expressions of disgust were performed with a larger mouth Distance than posed expressions.

The analysis on the upper part of the face, on the other hand, showed no differences in the kinematic components of face movement.

IRI

No strong correlations were found between kinematic measures and IRI subscales.

Distal movements

The repeated-measures ANOVA on the lateral marker pairs showed a significant difference between the Left and Right sides of the face with regard to the time to Maximum Distance of the mouth corners. In particular, the Maximum Distance was reached earlier in the Left than in the Right side of the face. In the upper part of the face, the Distance (absolute and delta) between the Eyebrows and the nose was greater on the Left than on the Right side of the face and the peak of Maximum Acceleration was anticipated in the Left eyebrow.

Emotional Contagion

The results on the horizontal axis (i.e., lower vs upper part of the face) support the concept that facial expressions of disgust are predominantly organized in the lower part of the face (Ross et al., 2016).

Results on the vertical axis (i.e., Left vs Right side of the face) showed that peak Distance was reached earlier in the Left than in the Right corner of the mouth. Moreover, the Left Eyebrow was more distal and its peak Acceleration was reached earlier than the Right Eyebrow. According to the Emotion Type Hypothesis (Ross et al., 1994, 2019), the right hemisphere mediates primary emotions, including disgust. These results fit well with this hypothesis, showing a supremacy of the right hemisphere in the expression of disgust.

The Right Hemisphere Hypothesis as well suggests a dominant right-hemisphere lateralization for all emotions. Whereas the Valence Hypothesis states that only negative emotions (e.g., disgust) would be lateralized in the right hemisphere. All these hypotheses are confirmed by my results on the Emotional Contagion of disgust.

Experiment 2

Methods

Participants

Seventeen participants (15 females and 10 males) aged between 20 and 29 years ($Mean_{age}$=23.118, SD=2.261) were recruited. Three participants were subsequently excluded due to poor registration for face tracking. None of them took part in Experiment 1.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous disgust was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 37 healthy volunteers (33 females, 4 males; age=18-55 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods). I selected the three video clips with the highest scores on the Likert and the SAM assessing arousal, and the lowest scores on the SAM assessing valence.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the delta parameter, and peaks of Velocity, Acceleration, and Deceleration parameters when the participants performed a posed expression of disgust, compared to when they are disgusted spontaneously (DDCH: $F_{(1,16)}$=14.029, p=0.002, VS-MPR=32.887; MVCH: $F_{(1,16)}$=11.753, p=0.003, VS-MPR=18.817; MACH: $F_{(1,16)}$=18.897, p<0.001, VS-MPR=96.924; MDecCH: $F_{(1,16)}$=12.366, p=0.001, VS-MPR=41.720; Figure 6.3 A-D). None of the temporal parameters revealed significant differences through conditions (all p_s > 0.05).

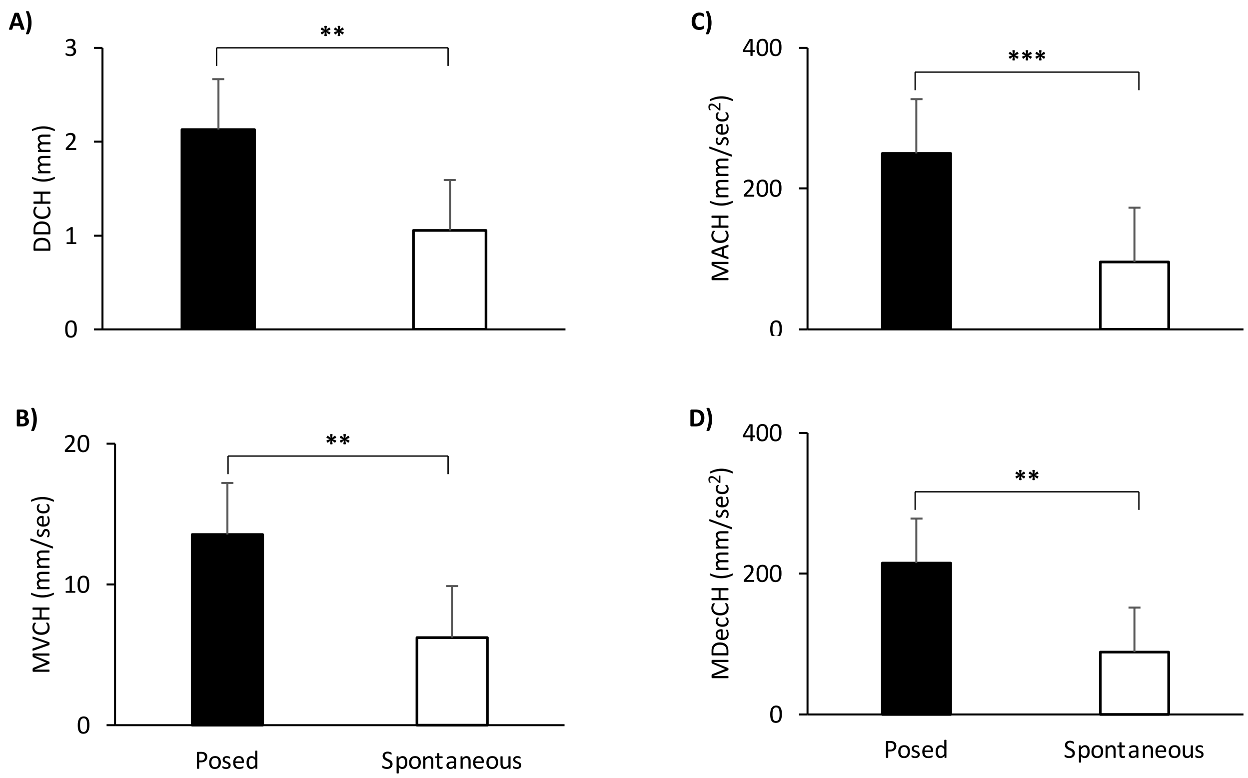

Figure 6.3. Graphical representation of spatial and speed components of movement during posed and spontaneous expressions of disgust. Lower part of the face: (A) Delta Distance (DDCH), (B) Maximum Velocity (MVCH), (C) Maximum Acceleration (MACH), (D) Maximum Deceleration (MDecCH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**= p<0.01; ***= p<0.001).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the delta parameters and peaks of Acceleration and Deceleration parameters when the participants performed a posed expression of disgust, compared to when they were spontaneously disgusted (DDEB: $F_{(1,16)}$=24.653, p<0.001, VS-MPR=295.391; MAEB: $F_{(1,16)}$=8.322, p=0.011, VS-MPR=7.535; MDecEB: $F_{(1,16)}$=19.816, p<0.001, VS-MPR=329.815; Figure 6.4 A-C). Moreover, this movement reached an earlier Maximum Distance and Acceleration peak when participants performed a posed expression of disgust than when actually disgusted (TMD%EB: $F_{(1,16)}$=5.889, p=0.027, VS-MPR=3.730; TMA%EB: $F_{(1,16)}$=10.278, p=0.003, VS-MPR=20.829; Figure 6.4 D-E). None of the remaining parameters revealed statistically significant differences through conditions (all p_s > 0.05).

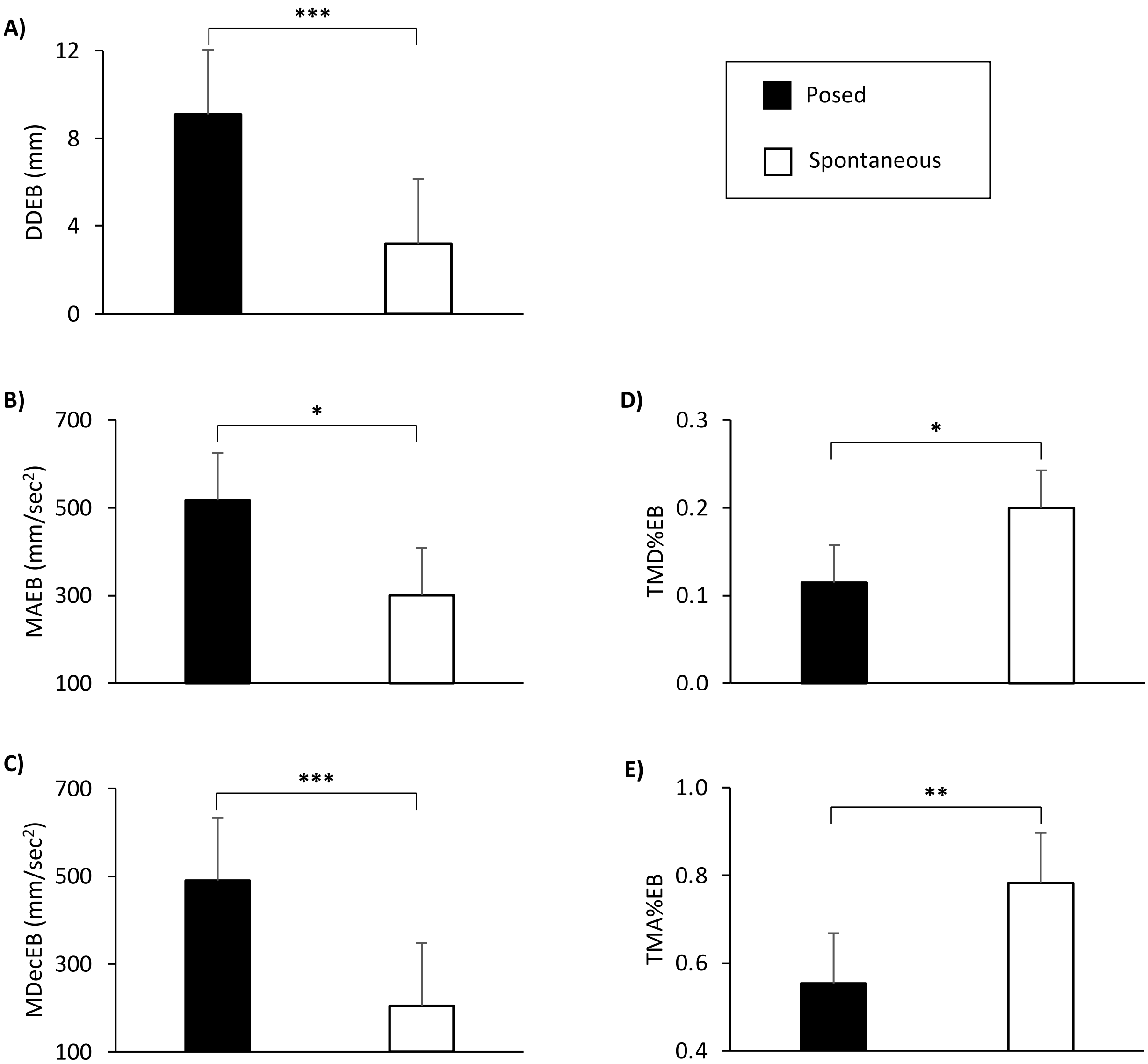

Figure 6.4. Graphical representation of spatial, speed, and temporal components of movement during posed and spontaneous expressions of disgust. Upper part of the face: (A) Delta Distance (DDEB), (B) Maximum Acceleration (MAEB), (C) Maximum Deceleration (MDecEB), (D) Time to Maximum Distance (TMD%EB), and (E) Time to Maximum Acceleration (TMA%EB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **= p<0.01; ***= p<0.001).

Correlations between IRI and kinematics measures

No strong correlations were found between the IRI subscales and the kinematic measures considered (Table 6.1).

Table 6.2. Pearson's Correlation between IRI subscales and kinematic measure of spontaneous expressions of disgust.

EXPRESSION	**IRI**		**DD CH**	**MV CH**	**MA CH**	**MDec CH**	**DD EB**	**MA EB**	**Mdec EB**	**TMD% EB**	**TMA% EB**
Posed	COG	PT	0.102	-0.072	0.087	-0.038	-0.068	0.235	-0.148	-0.122	0.367
		FS	-0.297	-0.238	-0.246	-0.042	0.012	-0.054	-0.190	0.056	0.077
	EMO	EC	0.210	0.137	-0.119	0.161	0.086	0.449	0.273	0.020	0.021
		PD	0.143	0.250	0.136	0.228	-0.079	-0.156	-0.104	-0.098	0.239
Spontaneous	COG	PT	0.344	0.450	0.373	0.447	0.536	0.425	0.424	0.013	0.034
		FS	-0.012	-0.064	-0.036	0.042	0.128	-0.266	-0.072	-0.191	0.203
	EMO	EC	0.215	0.233	0.188	0.046	0.142	0.305	-0.377	0.269	0.472
		PD	-0.214	-0.225	-0.122	-0.379	-0.015	-0.148	-0.317	-0.066	0.041

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

The lower part of the face - corners of the mouth

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,16)}$=20.665, p<0.001, VS-MPR=138.814, η^2_p=0.564) was found. The Delta was wider when the disgusted expression was posed than when it was spontaneous (2.347 and 0.663 mm, respectively).

Maximum Velocity (MV) | A significant main effect of the Condition ($F_{(1,16)}$=4.587, p=0.048, VS-MPR=2.526, η^2_p=0.223) was found. The peak Velocity was higher when the disgusted expression was posed than when it was spontaneous (7.864 and 4.957 mm, respectively).

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,16)}$=9.987, p=0.006, VS-MPR=11.884, η^2_p=0.384) was found. Acceleration peak was higher when the disgusted expression was posed than when it was spontaneous (252.397 and 122.928 mm/sec^2, respectively).

Maximum Deceleration (MDec) | A significant main effect of the Condition ($F_{(1,16)}$=10.288, p=0.005, VS-MPR=12.875, η^2_p=0.391) was found. Deceleration peak was higher when the disgusted expression was posed than when it was spontaneous (274.323 and 108.886 mm/sec^2, respectively).

Time to Maximum Velocity (TMV%) | A significant main effect of the Side of the Face ($F_{(1,16)}$=10.918, p=0.009, VS-MPR=8.552, η^2_p=0.548) was found. Velocity peak was reach earlier in the Left side of the face respect to the Right during disgusted expressions (36.8 and 48.6 %, respectively; Figure 6.5).

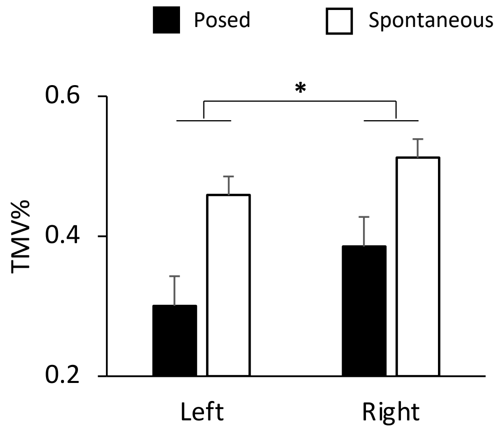

Figure 6.5. The graph shows the Time to Maximum Distance by the Left and Right Cheilions occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,16)}$=21.990, p<0.001, VS-MPR=179.850, η^2_p=0.579) was found. The delta was wider when the disgusted expression was posed than when it was spontaneous (2.928 and 1.902 mm, respectively).

Maximum Velocity (MV) | A significant interaction Condition by Side of the Face ($F_{(1,16)}$=4.865, p<0.05, VS-MPR=2.746, η^2_p=0.233) was found. Post hoc contrasts showed no significance.

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,16)}$=8.850, p=0.009, VS-MPR=8.355, η^2_p=0.371) was found. Acceleration peak was higher when the disgusted expression was posed than when it was spontaneous (372.763 and 213.801 mm/sec^2, respectively).

Maximum Deceleration (MDec) | A significant main effect of the Condition ($F_{(1,16)}$=24.444, p<0.001, VS-MPR=241.135, η^2_p=0.620) was found. Deceleration peak was higher when the disgusted expression was posed than when it was spontaneous (479.870 and 197.739 mm/sec^2, respectively).

Time to Maximum Distance (TMD%) | A significant main effect of the Condition ($F_{(1,16)}$=6.759, p=0.019, VS-MPR=4.819, η^2_p=0.297) was found. The Maximum Distance was reach earlier when the disgusted expression was posed than when it was spontaneous (11.75 and 32.35 %, respectively).

Time to Maximum Deceleration (TMDec%) | A significant main effect of the Condition ($F_{(1,16)}=5.016$, $p<0.05$, VS-MPR=2.823, $\eta^2_p=0.251$) was found. Deceleration peak was reach earlier when the disgusted expression was posed than when it was spontaneous (42.95 and 59.6 %, respectively).

INTERIM DISCUSSION – EXPERIMENT 2

Proximal movements

In Experiment 2, I found an opposite spatial trend compared to Experiment 1. In fact, here the Delta Distance of the corners of the mouth was wider for the Posed compared to the Spontaneous condition. As concerns the peak Velocity, Acceleration and Deceleration, they were higher in the posed than the spontaneous expressions.

Whereas in Experiment 1 no parameters were found to be statistically significant in the upper part of the face, in Experiment 2 spatial, speed and temporal parameters were statistically significant. In particular, the Delta Distance was wider, the peak Acceleration and Deceleration were higher, the maximum displacement of the eyebrows and the Acceleration peak were anticipated during the posed compared to the spontaneous expressions.

IRI

No strong correlations were found between kinematic measures and IRI subscales.

Distal movements

The main effect of the Condition (Posed vs. Spontaneous) was evident for the spatial (DD) and speed (MV, MA, MDec) parameters of face movements. Posed expressions showed a greater Distance between the corners of the mouth and the tip of the nose than spontaneous expressions in both the Right and Left side of the face. Furthermore, the peak Velocity, Acceleration and Deceleration were higher during the posed than the spontaneous expressions. In the upper part of the face, posed expressions required a greater amplitude range and higher Acceleration and Deceleration peaks with respect to spontaneous expressions. Furthermore, Maximum Distance and peak Deceleration were anticipated in posed than in spontaneous expressions. In terms of lateralization, the peak Velocity was reached earlier in the Left than in the Right side of the face.

Motor Contagion

Results on the horizontal axis showed a stable effect of the Condition in both the upper and lower parts of the face.

Looking at the results on the vertical axis (i.e., Left vs. Right side of the face), the Emotion Type Hypothesis (Ross et al., 1994, 2019) was confirmed also for the induction method adopted in Experiment 2: here I detected an earlier peak of Velocity in the LeftCH then in the RightCH. Furthermore, both the Right Hemisphere Hypothesis and the Valence Hypothesis were confirmed by the results on Motor Contagion.

Comparison analysis – Experiment 1 vs. 2

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Maximum Distance (MDCH) | A significant main effect of Condition was found ($F_{(1, 29)}$=10.893, p=0.003, VS-MPR=24.051, η^2_p=0.273). The interaction between Experiment and Condition was also statistically significant ($F_{(1,29)}$=6.355, p=0.017, VS-MPR=5.206, η^2_p=0.180; Figure 6.6 A). Post hoc comparisons revealed that posed expressions of disgust performed in Experiment 1 had a wider Distance than spontaneous expressions both within (p=0.003) and across (p=0.010) Experiments. Moreover, posed expressions of disgust performed in Experiment 2 showed a wider amplitude with respect to Experiment 1 (p=0.022).

Delta Distance (DDCH) | A significant interaction between Experiment and Condition was found ($F_{(1,29)}$=7.061, p=0.013, VS-MPR=6.643, η^2_p=0.196) but post hoc comparisons revealed no statistical difference (all $p_s > 0.05$).

Maximum Velocity (MVCH) | A significant interaction between Experiment and Condition was found ($F_{(1,29)}$=8.418, p=0.007, VS-MPR=10.565, η^2_p=0.225). Post hoc comparisons showed that posed expressions of disgust were wider compared to spontaneous expressions of disgust, but only in Experiment 2 (p=0.011).

Maximum Acceleration (MACH) | A significant main effect of Condition was found ($F_{(1,29)}$=8.321, p=0.007, VS-MPR=10.223, η^2_p=0.223). The interaction between Experiment and Condition factors was also significant ($F_{(1,29)}$=7.788, p=0.009, VS-MPR=8.526, η^2_p=0.212; Figure 6.6 B). Post hoc comparisons revealed that spontaneous expressions of disgust performed in Experiment 2 showed a decreased peak of Acceleration than posed expressions in both Experiment 2 (p=0.001) and Experiment 1 (p=0.017). Moreover, the peak of Acceleration was significantly higher for spontaneous expressions in Experiment 1 than in Experiment 2 (226.091 and 95.780 mm/sec^2, respectively, p=0.020).

Maximum Deceleration (MDecCH) | A significant main effect of Condition was found ($F_{(1,29)}$=7.082, p=0.013, VS-MPR=6.691, η^2_p=0.196). The interaction between Experiment and Condition factors was also significant ($F_{(1,29)}$=4.690, p=0.039, VS-MPR=2.923, η^2_p=0.139; Figure 6.6 C). Post hoc comparisons revealed that spontaneous expressions of disgust performed in Experiment 2 showed a lower peak Deceleration than posed expressions in both Experiment 2 (p=0.007) and Experiment 1 (p=0.004). Moreover, the peak Deceleration was significantly higher for spontaneous expressions in Experiment 1 than in Experiment 2 (212.125 and 88.625 mm/sec^2, respectively, p=0.012).

The effects on temporal parameters were not statistically significant (all p_s > 0.05).

Upper part of the face – Eyebrows (EB)

Delta Distance (DDEB) | A significant main effect of Condition was found ($F_{(1, 29)}$=11.432, p=0.002, VS-MPR=28.640, η^2_p=0.283). The interaction between Experiment and Condition factors was also significant ($F_{(1,29)}$=13.342, p=0.001, VS-MPR=52.454, η^2_p=0.315; Figure 6.6 D). Post hoc comparisons revealed that spontaneous expressions of disgust performed in Experiment 2 showed a smaller amplitude range than posed expressions (p<0.001). Spontaneous expressions of disgust in Experiment 2 had a smaller range amplitude than posed expression in Experiment 1 (p=0.010). Moreover, the amplitude was significantly wider for spontaneous expressions in Experiment 1 than in Experiment 2 (8.058 and 3.195 mm, respectively, p=0.006).

Maximum Deceleration (MDecEB) | A significant main effect of Condition was found ($F_{(1,29)}$=4.377, p=0.046, VS-MPR=2.585, η^2_p=0.144), but post hoc comparisons revealed no statistical difference (all p_s > 0.05).

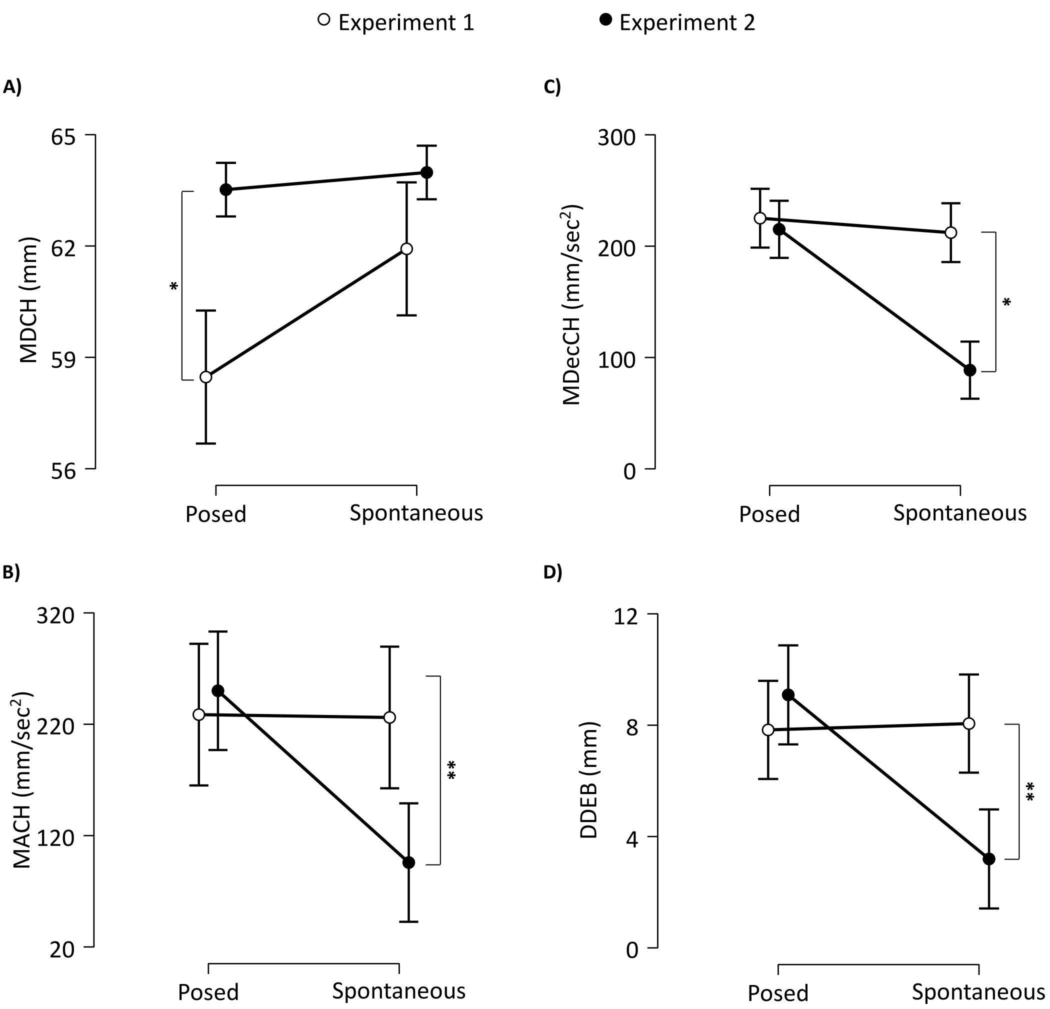

Figure 6.6. Graphical representation of spatial and speed components of movement in the lower part and upper part of the face during Posed and Spontaneous expressions of disgust in Experiments 1 and 2. (A) the Maximum Distance (MDCH), (B) peaks of Acceleration (MACH) and (C) Deceleration (MDecCH), and (D) delta Distance (DDEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **= p<0.01).

Mixed ANOVA: Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,29)}$=5.767, p=0.023, VS-MPR=4.245, η^2_p=0.166). Posed expressions had an increased range of mouth widening than spontaneous expressions (2.229 and 1.304 mm, respectively).

Maximum Acceleration (MA) | The 2-way interaction between Condition and Experiment was significant ($F_{(1,29)}$=6.706, p=0.05, VS-MPR=2.468, η^2_p=0.126). Post hoc comparisons revealed that in Experiment 2 posed expressions of disgust showed an increased peak Acceleration than spontaneous expressions (252.397 and 122.928 mm/sec^2, respectively; p=0.014; Figure 6.7 A).

Maximum Decelerations (MDec) | The 2-way interaction between Condition and Experiment was significant ($F_{(1,29)}$=9.379, p=0.005, VS-MPR=14.597, η^2_p=0.244). Post hoc comparisons revealed that in Experiment 2 posed expressions of disgust showed an increased peak Deceleration than spontaneous expressions (274.323 and 110,983 mm/sec^2, respectively; p=0.005; Figure 6.7 B).

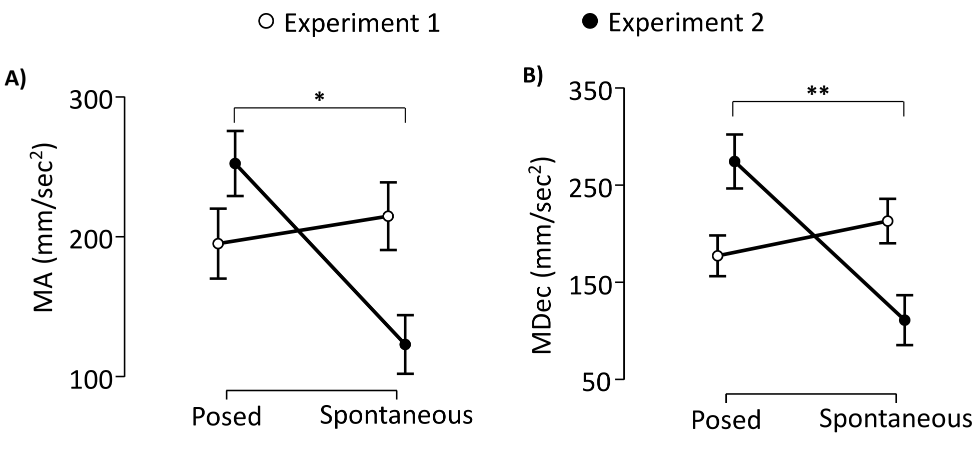

Figure 6.7. Graphical representation of Acceleration and Deceleration peaks of movement in the lower part of the face during Posed and Spontaneous expressions of disgust in Experiments 1 and 2. (A) the Maximum Acceleration (MA) and (B) Maximum Deceleration (MDec). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,29)}$=14.730, p<0.001, VS-MPR=80.323, η^2_p=0.337). The 2-way interactions between Condition and Experiment was significant ($F_{(1,29)}$=7.681, p=0.010, VS-MPR=8.220, η^2_p=0.209; Figure 6.8 A). Post hoc comparisons revealed that in Experiment 2 spontaneous expressions of disgust showed a smaller amplitude range than posed expressions in both Experiment 2 (p<0.001) and Experiment 1 (p<0.001). Moreover, the amplitude was significantly wider for spontaneous expressions in Experiment 1 than in Experiment 2 (p=0.004). The 2-way interactions between Side of the face and Experiment was also significant ($F_{(1,29)}$=9.105, p=0.005, VS-MPR=13.318, η^2_p=0.239; Figure 6.8 B). Post hoc comparisons revealed that in Experiment 1, the expressions of disgust showed a smaller range amplitude in the Left than in the Right Side of the face (p=0.005). Moreover, the Left Eyebrow was more distal in Experiment 1 than in Experiment 2 (p=0.033). In addition, the Left Eyebrow in Experiment 1 was more distal than the Right Eyebrow in Experiment 2 (p=0.041).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1,29)}$=8.022, p=0.008, VS-MPR=9.105, η^2_p=0.223). Posed expressions showed a higher peak of eyebrow Acceleration than spontaneous expressions (426.205 and 293.875 mm/sec^2, respectively).

Maximum Decelerations (MDec) | The main effect of Condition was significant ($F_{(1,29)}$=11.796, p=0.002, VS-MPR=31.341, η^2_p=0.296). Posed expressions showed a higher peak of eyebrow Deceleration than spontaneous expressions (518.293 and 317.790 mm/sec^2, respectively).

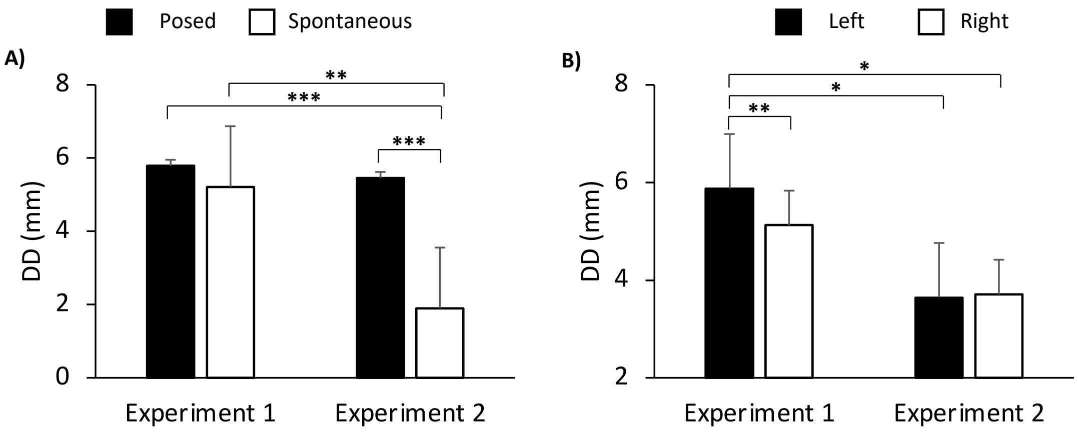

Figure 6.8. Graphical representation of Delta Distance in the upper part of the face during Posed and Spontaneous expressions of disgust in Experiments 1 and 2. (A) Two-way interaction Condition by Experiment and (B) Two-way interaction Side of the face by Experiment. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01*;* ***=p<0.*0*01).

Interim Discussion – Comparison Analysis

Results from two Experiments demonstrated that both proximal and distal facial movements provide consistent details to characterize and distinguish between spontaneous and posed expressions of disgust.

Proximal movements

Mixed ANOVA on the two experiments revealed that while Motor Contagion (Experiment 2) increased the peak Delta of posed expressions, Emotional Contagion (Experiment 1) increased the peak Velocity, Acceleration, and Deceleration of the corners of the mouth during spontaneous expressions. The peak Delta of the Eyebrows during spontaneous expressions was also increased for Experiment 1 compared to Experiment 2.

This means that when posed expressions of disgust were preceded by video clips framing disgusted faces (i.e., Motor Contagion), the amplitude of the corners of the mouth was larger than in Experiment 1. Whereas spontaneous expressions activated by Emotional Contagion in Experiment 1 were characterised by quicker movements of the mouth and increased distance of the Eyebrows.

In the expression of disgust, the temporal component of proximal face movement was not crucial to differentiate the two types of expression and the way they were induced.

Distal movements

A main effect of the condition in terms of spatial and speed parameters was also observed in the expression of disgust. Similarly to what occurred for the proximal movements in the upper part of the face, when spontaneous disgust was induced through Emotional Contagion (Exp1), the peak Delta was increased than in Experiment 2. An interesting effect emerged in the lateralised component of the eyebrow’s movement: the Left Eyebrow was more distal in Experiment 1 than in Experiment 2, for both types of expressions.

Emotional vs. Motor Contagion

The results on the horizontal axis (i.e., lower vs upper part of the face) confirm the hypothesis that facial expressions of disgust are predominantly organized in the lower part of the face (Ross et al., 2016). The induction method, however, played a crucial role in modulating this effect. In particular, posed expressions showed increased distances of the corners of the mouth after Motor Contagion. Whereas spontaneous expressions showed higher speed parameters of the mouth during Emotional Contagion. Even in the upper part of the face, spontaneous expressions induced by Emotional Contagion showed greater Distances than those induced by Motor Contagion.

The results on the vertical axis (i.e., Left vs. Right side of the face) also showed an interesting contribution of the spatial parameter: the Left Eyebrow was more distal during Experiment 1 than Experiment 2. This result on Emotional Contagion would partially confirm the three main Hypotheses on emotional lateralization (see Ross et al., 2019), given that movements of the Eyebrows are mediated by both the left and right hemisphere (see Figure 2.1). Not surprisingly, this lateralized result was found with spontaneous expressions and not with posed ones. Indeed, it is known that only a few people are able to move the two eyebrows independently on command (Schmidt et al., 2009).

7 | Experimental Chapter 4:

Anger

Anger is an intense emotional state involving a strong uncomfortable and non-cooperative response to a perceived provocation, hurt or threat (Alia-Klein et al., 2020)

In the facial expression of anger, eyebrows are centred (i.e., pulled down and together) and lips are tightened (Sowden et al., 2021). Variations in this expression (e.g., smiling in anger, gasping with widened eyes in anger) are simply explained as the result of processes that temporarily modify its prototypic expression, such as display rules, emotion-regulation strategies (e.g., suppressing the expression), or culture-specific dialects (Ekman & Cordaro, 2011; Elfenbein, 2013, 2017; Matsumoto, 1990; Matsumoto et al., 2008; Tracy & Randles, 2011). By contrast, other scientific frameworks propose that expressions of anger vary substantially across different people and situations. For example, when the goal of being angry is to overcome an obstacle, it may be more useful to scowl during some instances of anger, smile or laugh, or even stoically widen one's eyes, depending on the context (review Barrett et al., 2019). A slightly above chance co-occurrence of a facial configuration (i.e., scowling) and instances of anger demonstrated by a correlation coefficient (r) of about 0.20 to 0.39 (adapted from Haidt & Keltner, 1999) suggests that a person sometimes scowls in anger, but not most of the time.

Crucially, all these spatial and muscular description neglected the temporal component of angry faces. Only recently, Jack and colleagues (Delis et al., 2016; Jack et al., 2014; Jack & Schyns, 2015) demonstrated the crucial role of the temporal order of activation of the specific action units across emotional expressions (e.g., movement of the eyebrow region for expressions of anger and disgust). Notably, switching the order of key action units within a sequence of a specific emotion significantly impaired categorization of that emotion. Such work demonstrates the importance of the temporal order of activation of facial action units across emotional expressions. In the following experiments, I tried to better investigate not only the spatial and speed component, but also the temporal component of angry facial expressions.

EXPERIMENT 1

METHODS

Participants

Eleven participants (9 females and 2 males) aged between 22 and 32 years ($Mean_{age}$=25.400, SD=2.797) were recruited. Nine participants were subsequently excluded due to poor registration for face tracking (N=8) or technical/recording problems (N=1).

Stimuli and Procedure

For the Posed condition I adopted a static picture of disgust. Spontaneous disgust was instead elicited by using video clips inducing emotional contagion.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the peak Delta, Velocity and Acceleration when the participants performed a posed expression of anger, compared to when they were spontaneously angry (DDCH: $F_{(1,10)}$=5.788, p=0.037, VS-MPR=3.019; MVCH: $F_{(1,10)}$=9.241, p=0.012, VS-MPR=6.731; MACH: $F_{(1,10)}$=7.770, p=0.019, VS-MPR=4.847; Figure A-C). Moreover, this movement reached an earlier Acceleration peak during Posed than Spontaneous conditions (TMA%CH: $F_{(1,10)}$=5.889, p=0.027, VS-MPR=3.730; Figure 7.1 D). None of the remaining parameters revealed statistically significant differences through conditions (all p_s > 0.05).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the peak Delta, Acceleration and Deceleration when the participants performed a posed expression of anger, compared to when they were spontaneously angry (DDEB: $F_{(1,10)}=6.868$, $p<0.026$, VS-MPR=3.924; MAEB: $F_{(1,10)}=9.644$, $p=0.011$, VS-MPR=7.341; MDecEB: $F_{(1,10)}=7.102$, $p<0.024$, VS-MPR=4.148; Figure 7.1 E-G). Moreover, this movement reached an earlier peak Distance for posed than for spontaneous expressions (TMD%EB: $F_{(1,10)}=5.226$, $p=0.048$, VS-MPR=2.511; Figure 7.1 H). None of the remaining parameters revealed statistically significant differences through conditions (all $p_s > 0.05$).

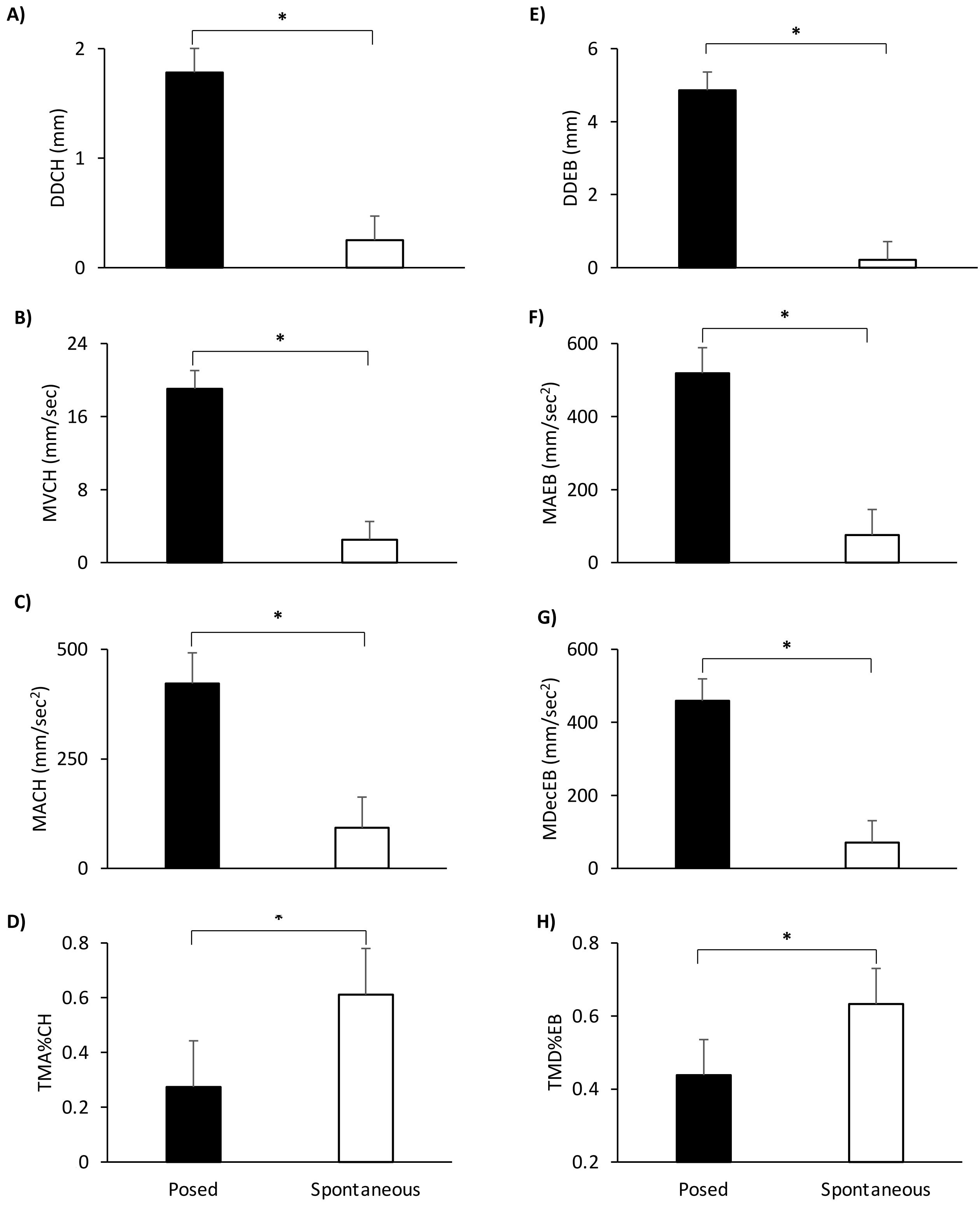

Figure 7.1. Graphical representation of spatial and speed components of movement during posed and spontaneous expressions of anger. Lower part of the face: (A) Delta Distance (DDCH), (B) Maximum Velocity (MVCH), (C) Maximum Acceleration (MACH), (D) Time to Maximum Acceleration (TMA%CH). Upper part of the face: (E) Delta Distance (DDEB), (F) Maximum Acceleration (MAEB), (G) Maximum Deceleration (MDecEB), and (H) Time to Maximum Distance (TMD%EB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=$p<0.05$).

CORRELATIONS BETWEEN IRI AND KINEMATICS MEASURES

Positive and negative correlations emerged between the IRI measurements and the spatial (DD), Velocity (MV, MA, MDec) and temporal (TMA% and TMD%) kinematic parameters, both in the lower and upper part of the face (i.e., the Cheilion and Eyebrow markers). In particular, in the lower part of the face, during the Posed Condition, the emotional subscale Personal Distress showed strong positive correlations between the measures of space (DD; r=0.651) and speed (MV and MA; r=0.848 and r=0.884, respectively). In the upper part of the face (i.e., the Eyebrows), strong and reliable correlations were found between the PD subscale and the speed measures (MA: r=0.687 and MDec: r=0.737; Table 7.1, Posed section). During the spontaneous condition, a negative correlation emerged between the PT subscale and the Maximum Acceleration time of the mouth corners (r=-0.673; Table 7.1, Spontaneous section).

Table 7.1. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions of anger.

EXPRESSION	IRI		DD CH	MV CH	MA CH	TMA% CH	DD EB	MA EB	MDec EB
Posed	COG	PT	-0.504	-0.398	-0.170	0.202	-0.297	-0.052	-0.167
		FS	0.033	0.232	0.317	0.534	-0.161	0.290	0.139
	EMO	EC	-0.038	0.035	0.088	0.331	-0.090	0.095	0.021
		PD	**0.651** *	**0.848** **	**0.884** **	0.468	0.508	**0.687** *	**0.737** *
Spontaneous	COG	PT	-0.306	0.282	0.043	**-0.673** *	0.122	0.329	0.277
		FS	-0.060	0.302	0.275	0.240	-0.264	0.126	0.305
	EMO	EC	0.255	0.355	0.317	0.144	0.244	0.514	0.420
		PD	0.162	0.324	0.434	0.128	-0.254	-0.103	0.183

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

The repeated-measures ANOVA on the movement of each Cheilion from the Tip of the Nose did not reveal a significant main effect of the Condition nor Side of the face (all $p_s > 0.05$).

Upper part of the face - Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | A significant main effect of the Condition was found (DD: $F_{(1,10)}=5.446$, $p=0.042$, VS-MPR=4.773, $\eta^2_p=0.353$) Posed expressions show a larger Delta Distance compared to spontaneous expressions (2.280 and 0.094 mm, respectively).

Maximum Acceleration (MA) | A significant main effect of the Condition was found ($F_{(1,10)}=9.805$, $p=0.011$, VS-MPR=7.595, $\eta^2_p=0.495$). Posed expressions show a higher peak Acceleration than spontaneous expressions (347.411 and 34.829 mm/sec^2, respectively).

Maximum Deceleration (MDec) | A significant main effect of the Condition was found (MDec: $F_{(1,10)}=7.737$, $p=0.024$, VS-MPR=4.127, $\eta^2_p=0.492$). Posed expressions show a higher peak Deceleration than spontaneous expressions (281.737 and 30.697 mm/sec^2, respectively).

Interim Discussion – Experiment 1

Proximal movements

The results of the Linear Mixed-effects Models indicate that the posed expressions of anger were performed with a greater Delta Distance, higher peak Velocity, Acceleration and Deceleration compared to the spontaneous expressions, both in lower and upper part of the face. Moreover, the Acceleration peak of the Cheilions was anticipated during the Posed than the Spontaneous condition. Also the maximum Eyebrow Distance was anticipated during posed expressions compared to spontaneous expressions.

IRI

For the Posed condition, five strong and very strong positive correlations were found between the emotional Personal Distress subscale and spatial and Velocity parameters, both in the lower and upper part of the face. Only a negative strong correlation was found between the Perspective Taking subscale and the percentage of time to Maximum Acceleration of the corners of the mouth during spontaneous expressions.

Distal movements

The results of the repeated-measures ANOVA showed no differences between Left and Right Cheilions nor between Left and Right Eyebrows. In the upper part of the face, the eyebrows' movement reached a greater Delta and a higher peak Acceleration and Deceleration during the posed expression of anger than during the spontaneous expressions.

Emotional Contagion

In terms of horizontal axis, both the lower and upper parts of the face seem to be particularly informative in distinguishing posed from spontaneous expressions of anger induced by Emotional Contagion. Sowden and colleagues (2021), on the other hand, recently found that the upper part of the face was crucial in distinguishing posed from spontaneous expressions of anger.

Along the vertical axis, no differences emerged between the left and right sides of the face in either the upper or lower parts. Thus, none of the three main Hypotheses on emotional lateralization (see

Ross et al., 2019) was confirmed by my results on the expression of anger induced with an Emotional Contagion paradigm.

EXPERIMENT 2

METHODS

Participants

Twenty participants (16 females and 4 males) aged between 20 and 29 years ($Mean_{age}$=23.381, SD=2.133) were recruited. None of them took part in Experiment 1.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous anger was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 45 healthy volunteers (34 females, 11 males; age=18-60 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods. I selected the three video clips with the highest scores on the Likert and the SAM assessing arousal, and the lowest scores on the SAM assessing valence.

Results

Linear Mixed Effect Models: Posed vs. Spontaneous Proximal Movements

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition, with an increase in all spatial and velocity parameters when participants performed a posed expression of anger compared with when they spontaneously displayed anger (MDCH: $F_{(1,19)}=21.670$, $p<0.001$, VS-MPR=246.050; DDCH: $F_{(1,19)}=31.165$, $p<0.001$, VS-MPR=1586.047; MVCH: $F_{(1,19)}=42.496$, $p<0.001$, VS-MPR=9535.247; MACH: $F_{(1,19)}=37.640$, $p<0.001$, VS-MPR=4579.175; MDecCH: $F_{(1,19)}=84.974$, $p<0.001$, VS-MPR=1078000; Figure 7.2 A-E). In addition, during posed condition, this movement showed a postponed Time to Maximum Distance, and an earlier peak Velocity and Acceleration (TMD%CH: $F_{(1,19)}=21.203$, $p<0.001$, VS-MPR=222.430; TMV%CH: $F_{(1,19)}=44.207$, $p<0.001$, VS-MPR=303854.159; TMA%CH: $F_{(1,19)}=8.763$, $p=0.005$, VS-MPR=13.306; Figure 7.2 F-H).

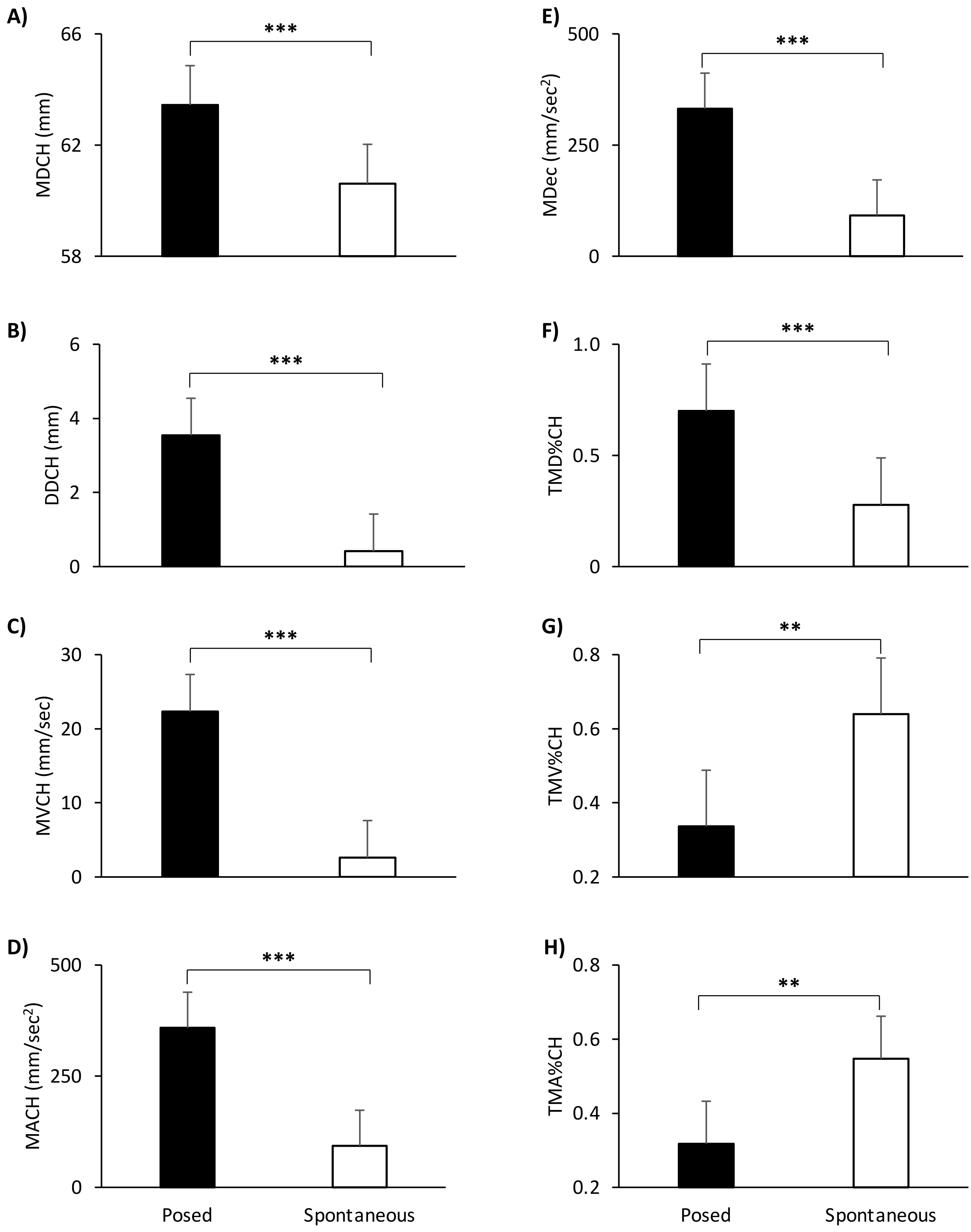

Figure 7.2. Graphical representation of spatial, speed, and temporal components of movement during posed and spontaneous expressions of anger. Lower part of the face: (A) Maximum Distance (MDCH), (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH), (D) Maximum Acceleration (MACH), (E) Maximum Deceleration (MDecCH), (F) Time to Maximum Distance (TMD%CH), (G) Time to Maximum Velocity (TMV%CH), and (H) Time to Maximum Acceleration (TMA%CH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***=p<0.001).

Upper part of the face – Eyebrows (EB)

Linear Mixed-Effect Models revealed a significant effect of the Condition, with an increase in Delta Distance and higher peaks in eyebrow speed when participants were performing a posed expression, compared to when they were spontaneously angry (DDEB: $F_{(1,28)}$=58.767, p<0.001, VS-MPR=882294.682; MAEB: $F_{(1,14)}$=79.077, p<0.001, VS-MPR=63677.612; MDecEB: $F_{(1,14)}$=46.938, p<0.001, VS-MPR=3954.7474; Figure 7.3 A-C). Furthermore, during posed condition, this movement showed earlier Times to Maximum Distance, Velocity, and Deceleration (TMD%EB: $F_{(1,28)}$=43.415, p<0.001, VS-MPR=65342.239; TMV%EB: $F_{(1,28)}$=43.013, p<0.001, VS-MPR=60605.420; TMDec%EB: $F_{(1,28)}$=16.287, p=0.001, VS-MPR=44.721; Figure 7.3 D-F).

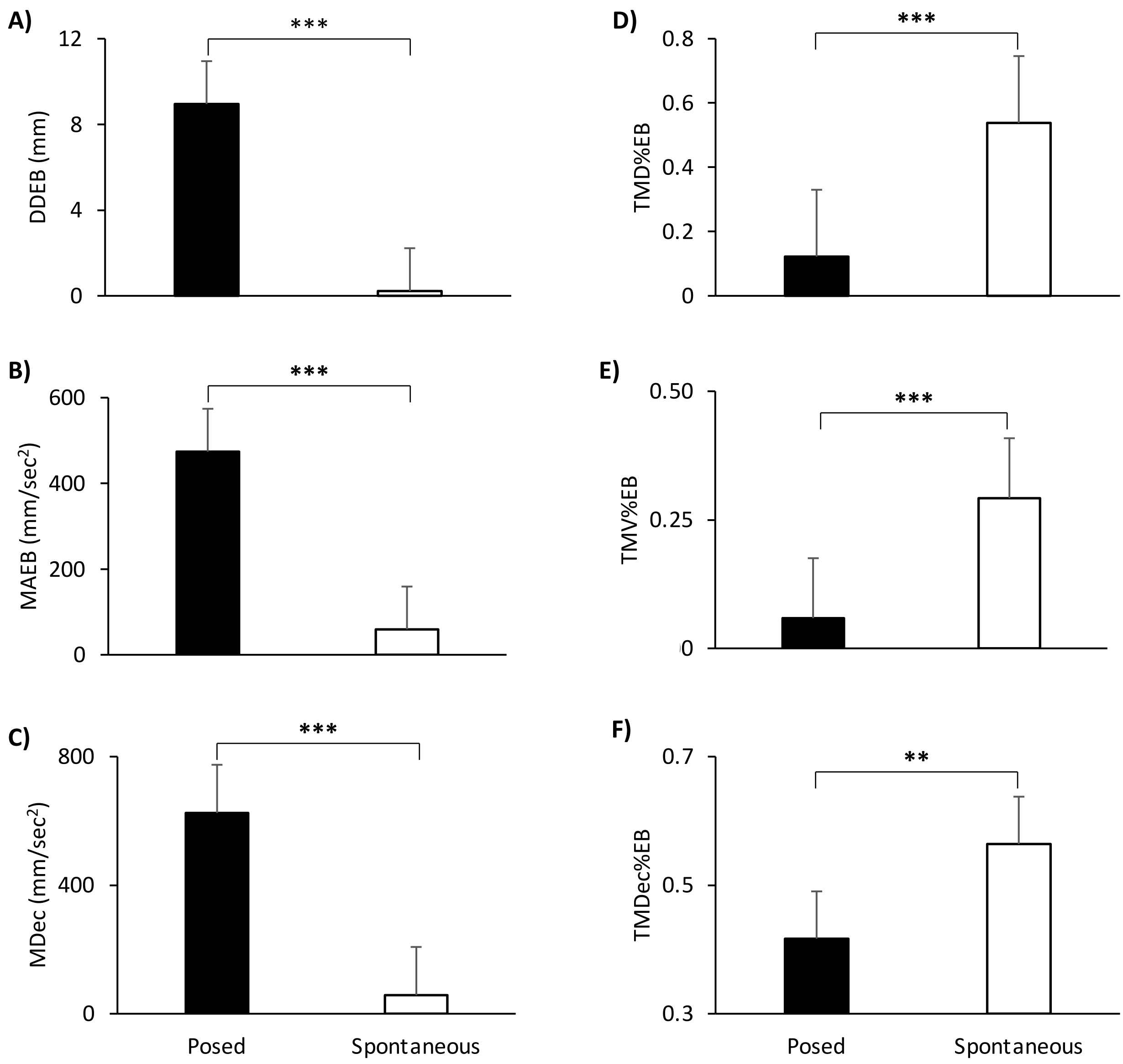

Figure 7.3. Graphical representation of spatial, speed, and temporal parameters of movement during posed and spontaneous expressions of anger. Upper part of the face: (A) Delta Distance (DDEB), (B) Maximum Acceleration (MAEB), (C) Maximum Deceleration (MDecEB), (D) Time to Maximum Distance (TMD%EB), (E) Time to Maximum Velocity (TMV%EB), and (F) Time to Maximum Deceleration (TMDec%EB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***=p<0.001).

Correlations between IRI and kinematics measures

No significant correlation emerged between the IRI subscales and the kinematic parameters of the posed anger condition. In the spontaneous condition, a statistically significant correlation emerged in the upper part of the face (i.e., Eyebrows). In particular, I found a strong negative correlation between PD (cognitive) and MDecEB (r=-0.609) (Table 7.2).

Table 7.2. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions.

EXPRESSION	IRI		DD CH	MV CH	MA CH	TMA% CH	DD EB	MA EB	MDec EB	TMD% EB
Posed	COG	PT	0.376	0.278	0.337	-0.015	-0.250	-0.104	-0.090	0.510
		FS	-0.349	-0.159	0.138	-0.272	-0.339	0.090	0.266	0.132
	EMO	EC	-0.324	-0.138	0.059	0.058	-0.184	-0.016	0.302	0.008
		PD	-0.334	-0.403	-0.242	-0.319	-0.247	-0.156	0.073	0.007
Spontaneous	COG	PT	-0.106	0.128	0.316	0.377	-0.167	-0.195	-0.493	-0.529
		FS	-0.064	-0.235	-0.159	0.330	0.126	-0.243	-0.268	-0.030
	EMO	EC	-0.051	-0.146	0.107	0.317	-0.508	-0.309	-0.440	-0.316
		PD	-0.073	-0.099	-0.094	0.305	-0.113	-0.531	**-0.609 ***	0.091

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, Right CH)

Delta Distance (DD) | A significant main effect of the Condition was found ($F_{(1,14)}$=13.535, p=0.002, VS-MPR=24.739, η^2_p=0.492). The amplitude range of the mouth was wider when the expression was posed than when it was spontaneous (1.543 and 0.315 mm, respectively).

Maximum Velocity (MV) | A significant main effect of the Condition was found ($F_{(1,15)}$=12.101, p=0.003, VS-MPR=19.183, η^2_p=0.447). The peak Velocity was higher when the expression of anger was posed than when it was spontaneous (5.687 and 2.898 mm/sec, respectively).

Maximum Acceleration (MA) | A significant main effect of the Condition was found ($F_{(1,15)}$=28.248, p<0.001, VS-MPR=454.300, η^2_p=0.653). The peak Acceleration was higher when the expression of anger was posed than when it was spontaneous (267.319 and 88.793 mm/sec^2, respectively).

Maximum Deceleration (MDec) | The main effect of Condition was significant ($F_{(1,17)}$=11.057, p=0.004, VS-MPR=16.636, η^2_p=0.394). The 2-way interactions between Condition and Side of the face was significant ($F_{(1,17)}$=5.197, p=0.036, VS-MPR=3.085, η^2_p=0.234). Post hoc comparisons revealed that posed expression of anger in the Right side of the face showed a higher peak of Deceleration than spontaneous expression in both the Left and Right side of the face (all p_s<0.01; Figure 7.4 A).

The upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,19)}$=8.181, p=0.010, VS-MPR=7.978, η^2_p=0.301) was found. The amplitude was wider when the expression was spontaneous than when it was posed (77.933 and 76.846 mm, respectively).

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,15)}$=76.488, p<0.001, VS-MPR=86343.060, η^2_p=0.836) was found. The amplitude range was wider when the expression was posed than when it was spontaneous (5.945 and 1.229 mm, respectively).

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,17)}$=93.860, $p<0.001$, VS-MPR=854059.226, η^2_p=0.847) was found. The peak Acceleration was higher when the expression of anger was posed than when it was spontaneous (307.621 and 59.980 mm/sec^2, respectively).

Maximum Deceleration (MDec) | A significant main effect of the Condition ($F_{(1,15)}$=102.228, $p<0.001$, VS-MPR=501991.520, η^2_p=0.872) was found. The peak Deceleration was higher when the expression of anger was posed than when it was spontaneous (372.575 and 51.080 mm/sec^2, respectively).

Time to Maximum Distance (TMD%) | Two significant main effects of the Condition ($F_{(1,19)}$=14.620, p=0.001, VS-MPR=50.577, η^2_p=0.422) and Side of the face ($F_{(1,19)}$=5.453, p=0.030, VS-MPR=3.491, η^2_p=0.214) were found. The 2-way interactions between Condition and Side of the face was also significant ($F_{(1,19)}$=5.519, p=0.029, VS-MPR=3.566, η^2_p=0.216). Post hoc comparisons revealed that spontaneous expression of anger showed a delayed peak Distance in the Left side of the face than posed expression both in the Left and Right side of the face (all $p_s<0.001$). Crucially, spontaneous expression of anger in the Left side of the face was reached later than spontaneous expression in the Right side (p=0.012; Figure 7.4 B).

Time to Maximum Velocity (TMV%) | A significant main effect of the Condition ($F_{(1,19)}$=13.697, p=0.001, VS-MPR=39.650, η^2_p=0.406) was found. The peak of speed was reached later when the expression was spontaneous than when it was posed (26.5 and 11.05 %, respectively).

Time to Maximum Acceleration (TMA%) | A significant main effect of the Condition ($F_{(1,19)}$=6.786, p=0.017, VS-MPR=5.220, η^2_p=0.263) was found. The peak of Acceleration was reached later when the expression was posed than when it was spontaneous (59.1 and 38.6 %, respectively).

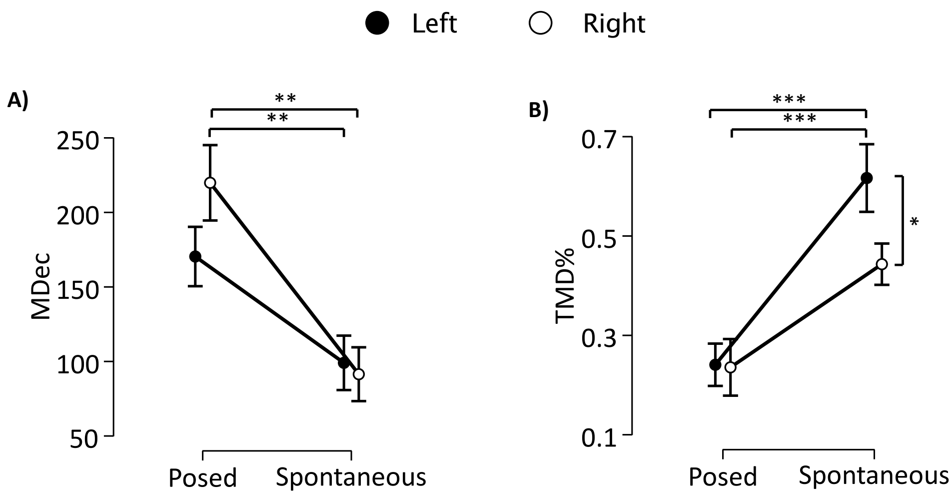

Figure 7.4. The graphs show: (A) Maximum Deceleration (MDec) reached by the Left and Right Cheilions occur across conditions and (B) Time to Maximum Distance (TMD%) reached by the Left and Right Eyebrows occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01; ***=p<0.001).

Interim Discussion – Experiment 2

Proximal movements

In Experiment 2, I found a consistency with Experiment 1 in the spatial and velocity parameters of proximal movements. Indeed, the peak Distance and Delta of the corners of the mouth were greater for the Posed than the Spontaneous condition. Furthermore, peak Velocity, Acceleration, and Deceleration were higher in the posed compared to the spontaneous expressions. In temporal terms, the time to peak Distance was delayed whereas the time to peaks Velocity and Acceleration were earlier for the posed than the spontaneous expressions. A similar trend was found in the upper part of the face: in spatial and velocity terms, posed expressions had larger peak Delta, Acceleration and Deceleration. In temporal terms, the time to peak Distance, Velocity and Acceleration was anticipated for posed compared to spontaneous expressions.

IRI

Only one strong correlation ($r \geq 0.6$) was found between statistically significant parameters for the expressions of anger in Experiment 2 and the IRI questionnaire. In particular,

The Deceleration peak between the eyebrows was lower in the Spontaneous condition for those with high scores on the Emotional Personal Distress scale.

Distal movements

Posed expressions showed a higher peak Delta Distance between the corners of the mouth and the tip of the nose than spontaneous expressions. In terms of speed, I observed higher peaks for Velocity, Acceleration, and Deceleration during the posed expressions than during the spontaneous expressions. On the upper Side of the face, posed expressions showed higher values for Maximum Distance, Deltas, Maximum Velocity, Acceleration, and Deceleration.

In lateralised terms, the peak Deceleration of the Right Cheilion was greater for posed than for spontaneous expressions. Moreover, the peak Distance between the Left eyebrow and the tip of the nose during spontaneous expression was postponed compared to the Right side of the face. The Left eyebrow Distance was also postponed during spontaneous expressions compared to posed expressions. Furthermore, the time to reach the maximum speed and Acceleration were postponed during the posed conditions compared to the spontaneous ones.

Motor Contagion

Regarding the horizontal axis, the Cheilion markers appear to be crucial in distinguishing the two types of expressions. This confirm recent findings from Sowden and colleagues (2021), who indicated that only the lower part of the face would be crucial in this distinction.

Along the vertical axis, a difference emerged between Left and Right sides of the face during spontaneous expressions: the peak Distance of the Left Eyebrow was postponed compared to the Right Eyebrow. During posed expressions, on the other hand, the peak Distance of the Left Eyebrow was anticipated compared to the spontaneous expressions. This result for posed expressions is in agreement with the three main Hypotheses on emotional lateralization (see Ross et al., 2019).

Comparison analysis – Experiment 1 vs. 2

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Maximum Distance (MDCH) | A significant main effect of Condition was found ($F_{(1,24)}=16.156$, $p<0.001$, VS-MPR=96.523, $\eta^2_p=0.402$). Posed expressions were wider than spontaneous expressions (62.401 and 60.244 mm, respectively). The interaction between Experiment and Condition was also statistically significant ($F_{(1,24)}=4.429$, $p=0.046$, VS-MPR=2.598, $\eta^2_p=0.156$). Post hoc comparisons revealed that posed expressions of anger performed in Experiment 2 showed a wider Distance than spontaneous expression ($p<0.001$) (Figure 7.5 A).

Delta Distance (DDCH) | A significant main effect of Condition was found ($F_{(1,24)}=85.171$, $p<0.001$, VS-MPR=1831.927, $\eta^2_p=0.541$). The interaction between Experiment and Condition was also statistically significant ($F_{(1,24)}=4.739$, $p=0.040$, VS-MPR=2.879, $\eta^2_p=0.165$). Post hoc comparisons revealed that posed expression of anger performed in Experiment 2 showed a wider Distance than spontaneous expression performed in Experiment 1 and Experiment 2 (all $p_s<0.001$). Moreover, posed expression of anger performed in Experiment 2 also showed a wider Distance than posed expression performed in Experiment 1 ($p=0.009$) (Figure 7.5 B).

Maximum Velocity (MVCH) | A significant main effect of Condition was found ($F_{(1,24)}=36.297$, $p<0.001$, VS-MPR=9069.097, $\eta^2_p=0.602$). The peak speed was higher for posed than spontaneous expressions (21.553 and 2.371 mm/sec, respectively).

Maximum Acceleration (MACH) | A significant main effect of Condition was found ($F_{(1,24)}=25.705$, $p<0.001$, VS-MPR=1029.466, $\eta^2_p=0.517$). The Acceleration peak was higher for posed than spontaneous expressions (400.554 and 92.289 mm/sec^2, respectively).

Maximum Deceleration (MDecCH) | A significant main effect of Condition was found ($F_{(1,24)}=55.346$, $p<0.001$, VS-MPR=160366.666, $\eta^2_p=0.706$). The Deceleration peak was higher for posed than spontaneous expressions (294.890 and 95.519 mm/sec^2, respectively).

Time to Maximum Acceleration (TMA%CH) | A significant main effect of Condition was found ($F_{(1,24)}$=14.200, p<0.001, VS-MPR=53.330, η^2_p=0.382). The Acceleration peak was anticipated for posed than spontaneous expressions (27.0 and 57.5 %, respectively).

Upper part of the face – Eyebrows (EB)

Delta Distance (DDEB) | A significant main effect of Condition was found ($F_{(1,24)}$=43.549, p<0.001, VS-MPR=32904.350, η^2_p=0.654). Posed expressions shoed wider Distance than spontaneous expressions (6.906 and 0.219 mm, respectively).

Maximum Acceleration (MAEB) | A significant main effect of Condition was found ($F_{(1,24)}$=41.571, p<0.001, VS-MPR=23473.858, η^2_p=0.634). The Acceleration peak was higher for posed than spontaneous expressions (496.342 and 67.318 mm/sec^2, respectively).

Maximum Deceleration (MDecEB) | A significant main effect of Condition was found ($F_{(1,24)}$=36.823, p<0.001, VS-MPR=10006.994, η^2_p=0.605). The Deceleration peak was higher for posed than spontaneous expressions (541.868 and 64.197 mm/sec^2, respectively).

Time to Maximum Distance (TMD%EB) | A significant main effect of Condition was found ($F_{(1,23)}$=24.132, p<0.001, VS-MPR=650.631, η^2_p=0.512). The interaction between Experiment and Condition was statistically significant ($F_{(1,23)}$=4.875, p=0.037, VS-MPR=2.989, η^2_p=0.175). Post hoc comparisons revealed that, posed expression performed in Experiment 2 showed an anticipated Maximum Distance than spontaneous expressions of Experiment 1 and 2 (all p_s<0.001). Moreover, posed expression of Experiment 2 was also anticipated than the same expression performed in Experiment 1 (p=0.003) (Figure 7.5 C).

Time to Maximum Velocity (TMV%EB) | A significant main effect of Condition was found ($F_{(1,23)}$=20.841, p<0.001, VS-MPR=275.484, η^2_p=0.471). Posed expression showed an earlier Velocity peak than spontaneous expression of anger (13.1 and 29.3 %, respectively).

Time to Maximum Deceleration (TMDec%EB) | A significant main effect of Condition was found ($F_{(1,23)}$=18.606, p<0.001, VS-MPR=172.688, η^2_p=0.447). Posed expression showed an earlier Deceleration peak than spontaneous expression of anger (47.0 and 58.6 %, respectively).

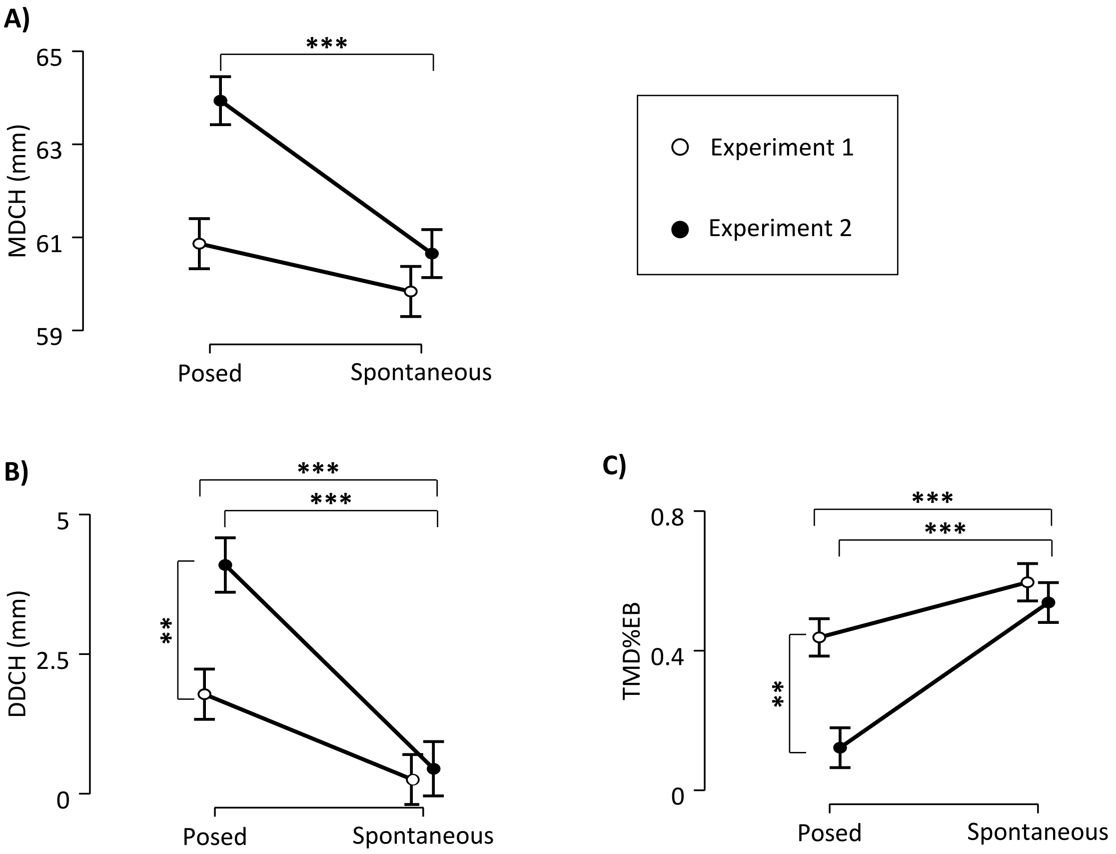

Figure 7.5. The graphs show: (A) Maximum Distance (MDCH) and (B) Delta Distance (DDCH) reached by the Left and Right Cheilions occur across conditions. (C) Time to Maximum Distance (TMD%EB) reached by the Left and Right Eyebrows occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***=p<0.001).

Mixed ANOVA: Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,21)}$=14.112, p=0.001, VS-MPR=46.882, η^2_p=0.402). Posed expressions had an increased range of widening than spontaneous expressions (1.380 and 0.257 mm, respectively).

Maximum Velocity (MV) | The main effect of Condition was significant ($F_{(1,25)}$=10.831, p=0.003, VS-MPR=21.284, η^2_p=0.302). Posed expressions showed higher Velocity peak than spontaneous expressions (6.489 and 2.411 mm/sec, respectively).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1,25)}$=20.110, p<0.001, VS-MPR=292.768, η^2_p=0.446). Posed expressions showed a higher peak of Acceleration than spontaneous expressions (242.736 and 80.679 mm/sec^2, respectively).

Maximum Deceleration (MDec) | The main effect of Condition was significant ($F_{(1,23)}$=63.942, p<0.001, VS-MPR=501858.827, η^2_p=0.735). Posed expressions showed a higher peak of Deceleration than spontaneous expressions (216.712 and 75.936 mm/sec^2, respectively).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,27)}$=36.150, p<0.001, VS-MPR=13717.458, η^2_p=0.572). Posed expressions had an increased range widening than spontaneous expressions (3.599 and 0.128 mm, respectively).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1,27)}$=44.639, p<0.001, VS-MPR=69034.389, η^2_p=0.623). Posed expressions showed a higher peak of Acceleration than spontaneous expressions (327.197 and 51.748 mm/sec^2, respectively).

Maximum Deceleration (MDec) | The main effect of Condition was significant ($F_{(1,27)}$=44.639, p<0.001, VS-MPR=69034.389, η^2_p=0.623). The 2-way interaction between Condition and Experiment was significant ($F_{(1,23)}$=6.646, p=0.017, VS-MPR=5.355, η^2_p=0.244). Post hoc comparisons revealed that posed expressions of anger performed in Experiment 1 showed an increased Deceleration peak than posed expression performed in Experiment 2 ($p<0.001$) and spontaneous expressions of both Experiments ($p_s<0.05$). Moreover, posed expression performed in Experiment 2 highlighted an increased Deceleration peak than spontaneous expressions of both Experiments ($p_s<0.001$).

Time to Maximum Distance (TMD%) | The main effect of Condition was significant ($F_{(1,29)}=8.718$, $p=0.006$, VS-MPR=11.691, $\eta^2_p=0.231$). The Maximum Distance of the eyebrows to the tip of the nose was reached earlier during posed condition the spontaneous one (31.6 and 54.1 %, respectively).

Time to Maximum Velocity (TMV%) | The main effect of Condition was significant ($F_{(1,29)}=13.359$, $p=0.001$, VS-MPR=52.725, $\eta^2_p=0.315$). The Maximum Velocity was achieved earlier during posed condition than the spontaneous one (15.0 and 28.6 %, respectively).

Interim Discussion – Comparison Analysis

Results from two Experiments demonstrated that both proximal and distal facial movements provide relevant and consistent details to characterize and distinguish between spontaneous and posed expressions of anger.

Proximal movements

Mixed ANOVA on the two experiments revealed that Motor Contagion (Experiment 2) had a specific effect on the spatial parameters (MD and DD) of facial movement. In particular, during the Posed condition, the amplitude of the Cheilions varied depending on both the Condition and the Method of induction. Indeed, when the expression was induced by video clips framing angry faces (i.e., Motor Contagion) the Distance was increased for the Posed compared to the Spontaneous condition.

In the upper part of the face, the Time to Maximum Distance was anticipated during posed expressions performed after watching angry people (i.e., Motor Contagion).

A wide effect of the Condition was found both in the lower and upper part of the face. In fact, posed expression of anger showed higher peak Velocity, Acceleration, and Deceleration.

Distal movements

An interesting effect emerged in the speed parameter of the Eyebrows. When posed expressions of anger were induced through Emotional Contagion (Exp1), the Deceleration peak was increased compared to when they were induced by Motor Contagion (Exp2).

Emotional vs. Motor Contagion

Comparing the two induction methods, a crucial component in the lower part of the face emerged, characterized by an amplification of expression (i.e., wider Distance) during Motor Contagion, and in the upper part, characterized by an early peak Distance in posed than in spontaneous expressions. These results partially confirm the findings from Sowden and colleagues (2021), who found a distinctive feature in the upper part of the face.

Along the vertical axis, no difference emerged between Left and Right sides of the face. These results do not confirm any of the three main Hypotheses on the lateralization of emotions (see Ross et al., 2019), according to which anger is mainly mediated by the right hemisphere and would have a direct impact on the left hemiface.

8 | Experimental Chapter 5:

Sadness

The sad expression is related to a feeling of looseness which is normally expressed as rising eyebrows and lowering corners of the mouth (Arias et al., 2020). In particular, according to the FACS method, the corners of the mouth are pulled down while the eyebrows are pulled together and up in the middle.

During Covid-19 pandemic, the use of face masks has been said to impact face-to-face interaction negatively. Notably, emotion expressions are not only perceived but also responded to. One important behaviour in response to observing emotion expressions is in fact emotional mimicry, the spontaneous imitation of an interaction partner's emotional display (Hess & Fischer, 2013). In the past literature it was proposed that people tend to mimic other's expressions even if they are only partially visible (Blaison et al., 2013). However, a recent online experiment on 200 participants (UK sample) assessed facial mimicry in response to masked faces and found a divergent effect (Kastendieck et al., 2022). In that online study, participants saw a series of happy and sad face video stimuli while their facial activity was recorded by their webcam and then analysed in terms of facial action units as classified in the FACS (Ekman & Friesen, 1978). The results showed that mimicry was reduced in response to happy, but preserved for sad expressions, suggesting sadness mimicry may be relatively unimpeded by masks. In particular, participants showed less mimicry when they perceived happiness less intensely, whereas mimicry of sad expressions was not influenced by perceived emotion intensity. This may be because sadness is a strong elicitor of empathy (Scarantino, 2019) and it may also attract the observer at a more basic level.

I suggest that this divergent effect for the two expressions might be also due to the crucial role played by the upper face in the expression of sadness rather than happiness. To deeply investigate this topic, I run two Experiments manipulating the methods of induction and measuring the relative role of lower and upper face movements.

Experiment 1

Methods

Participants

Three participants out of 20 were analysed. They were females aged between 24 and 32 years ($Mean_{age}$=26.67, SD=4.62). 17 participants were in fact excluded due to drop out in the Posed condition (N=15) or technical/recording problems (N=2).

Stimuli and Procedure

For the Posed condition I adopted a static picture of sadness. Spontaneous sadness was instead elicited by using video clips inducing emotional contagion.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

Linear Mixed-Effect Models did not reveal a significant effect in the lower part of the face. The spatial, Velocity and temporal parameters were not statistically significant (all $p_s > 0.05$).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the peak Acceleration and Deceleration when participants performed a posed expression of sadness, compared to when they displayed a spontaneous expression of sadness (MAEB: $F_{(1,4)}=8.507$, p=0.043, VS-MPR=2.703; MDecEB: $F_{(1,4)}=8.018$, p=0.047, VS-MPR=2.570; Figure 8.1). None of the spatial and temporal parameters revealed statistically significant differences through conditions (all $p_s > 0.05$).

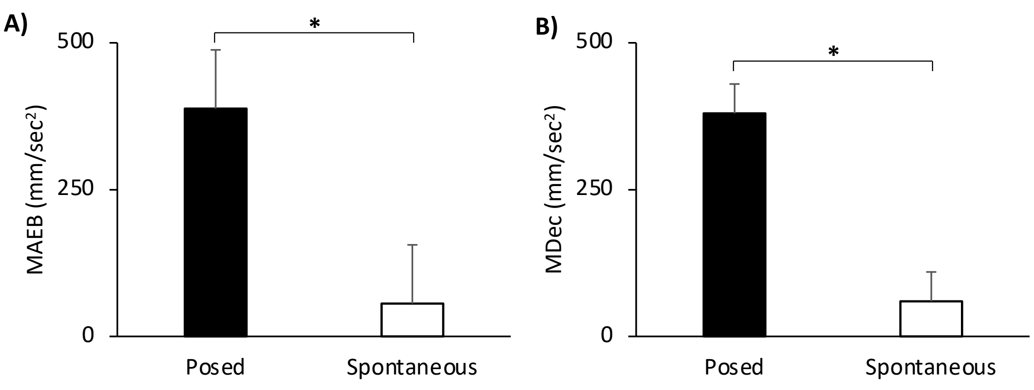

Figure 8.1. Graphical representation of Acceleration and Deceleration parameters of movement during posed and spontaneous expressions of sadness. Upper part of the face: (A) Maximum Acceleration (MAEB) and (B) Maximum Deceleration (MDecEB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05).

Correlations between IRI and kinematics measures

Positive correlation emerged the IRI subscales and Acceleration and Deceleration peaks relative to the upper part of the face (i.e., Eyebrows markers). In the Posed Condition, two very strong positive correlations emerged between MA and the subscales FS and EC. In addition, two very strong correlations were found between MDec and emotional subscales (EC and PD). A negative correlation was also found between MDec and PT (cognitive subscale). In spontaneous condition, strong and very-strong negative correlations emerged between both kinematic measures and the subscales FS, EC, PD (Table 8.1).

Table 8.1. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions.

EXPRESSION	IRI		MA EB	Mdec EB
Posed	COG	PT	0.149	**-0.676** *
		FS	**0.960** **	0.386
	EMO	EC	**0.826** **	**0.957** **
		PD	0.316	**0.937** **
Spontaneous	COG	PT	0.365	0.213
		FS	**-0.692** *	**-0.798** **
	EMO	EC	**-0.997** **	**-0.973** **
		PD	**-0.748** *	**-0.633** *

REPEATED-MEASURES ANOVA: POSED VS. SPONTANEOUS DISTAL MOVEMENTS

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,2)}$=26.177, p=0.05, VS-MPR=3.066, η^2_p=0.929) was found. Posed expressions of sadness were wider compared to spontaneous expressions of sadness both in the Left and Right sides of the face. A significant interaction Condition by Side of the Face ($F_{(1,2)}$=120.037, p=0.008, VS-MPR=9.134, η^2_p=0.984) was also found. However, post hoc contrasts showed no significance.

The upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,2)}$=20.532, p=0.045, VS-MPR=2.620, η^2_p=0.911) was found. The Acceleration peak was higher when the sad expression was posed than when it was spontaneous (246.319 and 10.559 mm/sec^2).

The spatial and temporal parameters were not statistically significant (all p_s > 0.05).

Interim Discussion – Experiment 1

Proximal movements

The results of the Linear mixed-effects models indicate that the only difference between posed and spontaneous expressions of sadness was in the upper part of the face: peak Acceleration and Deceleration of the Eyebrows were higher for the Posed condition.

IRI

Strong and very strong correlations between statistically significant parameters for the expressions of sadness in Experiment 1 and the IRI questionnaire were found only in the upper part of the face. During the Posed condition, very-strong positive correlations were found between the Fantasy subscale and peak Acceleration between the Empathic Concern subscale and the peaks of Acceleration and Deceleration, and between the subscale of Personal Distress and the peak Deceleration. Also, a strong negative correlation was found between this parameter and the subscale of Perspective Taking. For the Spontaneous condition, negative correlations were found between the Fantasy, the Empathic Concern and the Personal Distress subscales with both peak Acceleration and Deceleration. However, these results are unreliable due to the limited number of participants who completed the task and they will need to be confirmed by future studies.

Distal movements

Repeated-measures ANOVA showed that posed expressions were characterised by a greater distal movement of the Cheilions (i.e., the corners of the mouth were pulled down) and a higher peak Acceleration of the Eyebrows while they were pulled up with respect to spontaneous expressions.

Emotional Contagion

In the lower part of the, no spatial, speed or temporal parameter was found significant when distinguishing posed and spontaneous expression (except that corners of the mouth were more pulled down for posed than for spontaneous expressions). In the upper part of the face, instead, speed parameters for both proximal and distal movements were higher during the Posed compared to the Spontaneous condition. These results - showing a specific contribution of the upper part of the face rather than the lower part during the expression of sadness, would help explaining recent findings on the divergent role of face masking in mimicking expressions of happiness and sadness (Kastendieck et al., 2022). On the other hand, these results on Emotional Contagion seem to be in contrast with the hypothesis of Ross and colleague (2019), who identified the lower part of the face as more informative than the upper part for characterizing the two types of expression.

Along the vertical axis (i.e., Left vs Right side of the face), no difference emerged in either the lower or the upper part of the face.

According to the FACS method, the corners of the mouth are pulled down while the eyebrows are pulled up in the expression of sadness. My results from the Emotional Contagion paradigm showed that this pattern is, in fact, true for posed but not for spontaneous expressions of disgust. This finding reminds us once again to clearly distinguish expressions conveyed by the Voluntary or Involuntary pathway (Morecraft et al., 2004; Ross et al., 2016).

Experiment 2

Methods

Participants

Ten participants out of 20 (8 females and 2 males) aged between 21 and 27 years ($Mean_{age}$=24.400, SD=1.578) were analysed. 10 participants were excluded due to poor registration for face tracking (N=9) or technical/recording problems (N=1). None of them took part in Experiment 1.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous sadness was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 39 healthy volunteers (30 females, 9 males; age=18-60 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods). I selected the three video clips with the highest scores on the Likert and the SAM assessing the arousal, and with the lowest scores on the SAM assessing the valence.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the peak Delta and Velocity when the participants performed a posed expression of sadness, compared to when they spontaneously displayed sadness (DDCH: $F_{(1,18)}$=5.425, p=0.032, VS-MPR=3.363; MVCH: $F_{(1,18)}$=4.882, p=0.04, VS-MPR=2.841; Figure 8.2, Panels A-B). In addition, peak Velocity and Deceleration were achieved earlier for the posed than the spontaneous expressions (TMD%CH: $F_{(1,9)}$=5.609, p=0.042, VS-MPR=2.762; TMDec%CH: $F_{(1,9)}$=5.135, p=0.05, VS-MPR=2.467; Figure 8.2, Panels C-D).

Upper part of the face – Eyebrows (EB)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of the peak Delta, Acceleration and Deceleration when the participants performed a posed expression of sadness, compared to when they spontaneously displayed sadness (DDEB: $F_{(1,16)}$=17.452, p<0.001, VS-MPR=71.371; MAEB: $F_{(1,9)}$=17.476, p=0.02, VS-MPR=25.639; MDecEB: $F_{(1,9)}$=13.156, p=0.006, VS-MPR=12.837; Figure 8.2 Panels E-G). Moreover, this movement reached an earlier peak Velocity when participants performed a posed than a spontaneous expression of sadness sad (TMV%EB: $F_{(1,9)}$=5.126, p=0.05, VS-MPR=2.461; Figure 8.2, Panel H). None of the remaining parameters revealed statistically significant differences through conditions (all p_s > 0.05).

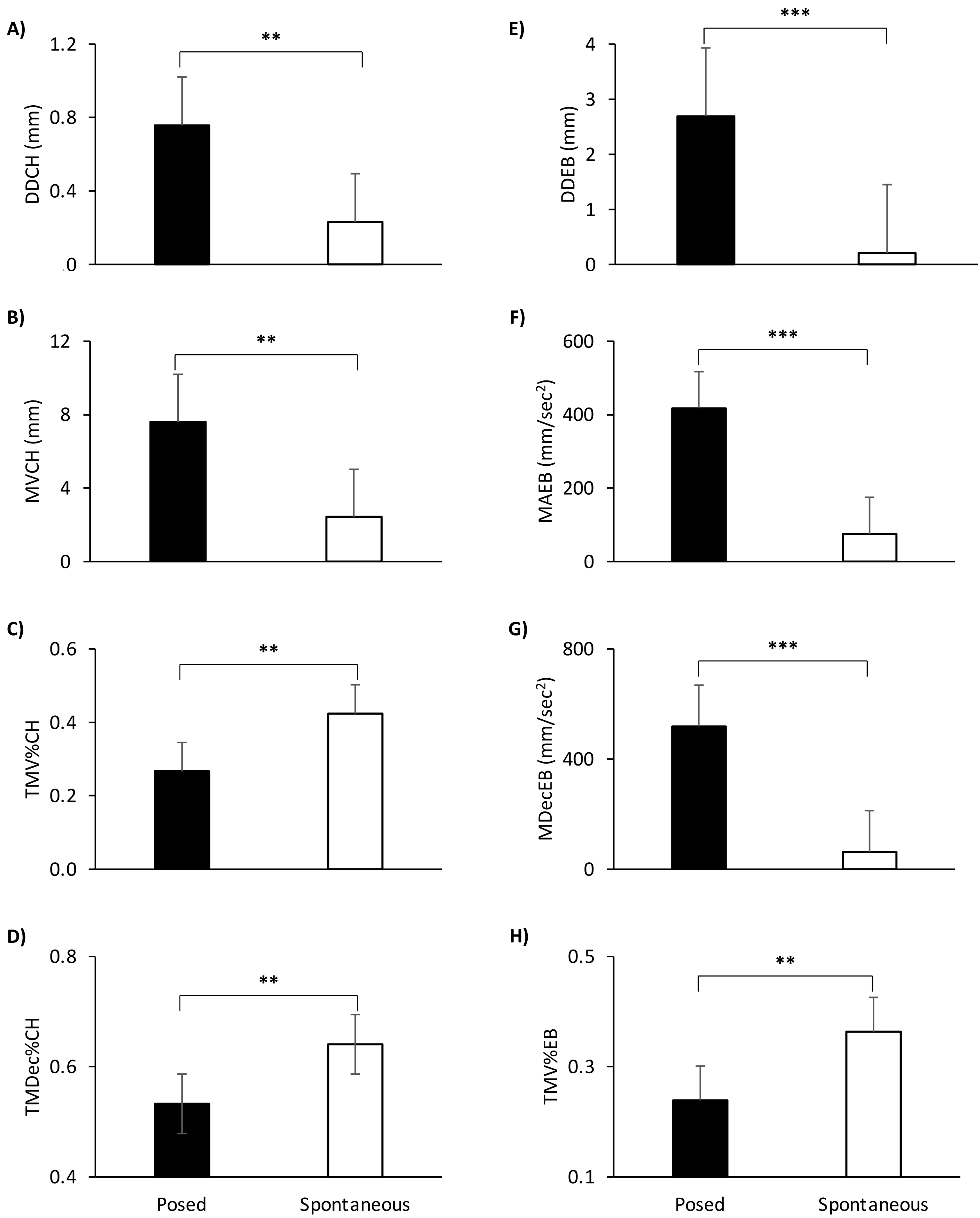

Figure 8.2. Graphical representation of spatial and speed components of movement during posed and spontaneous expressions of sadness. Lower part of the face: (A) Delta Distance (DDCH), (B) Maximum Velocity (MVCH), (C) Time to Maximum Velocity (TMV%CH) and, (D) Time to Maximum Deceleration. Upper part of the face: (E) Delta Distance (DDEB), (F) Maximum Acceleration (MAEB), (G) Maximum Deceleration (MDecEB) Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***= p<0.001).

CORRELATIONS BETWEEN IRI AND KINEMATICS MEASURES

For the Posed condition, strong correlations emerged on the spatial, Velocity, and temporal parameters (DD, MV, TMDec%) of the lower part of the face (i.e., Cheilion markers). In particular, negative correlations were found between the Fantasy subscale and peak Distance and Velocity, and between the Empathic Concern subscale and the Time to peak Deceleration. Positive correlations emerged between the Personal Distress subscale and both peak Distance and Velocity. For the Spontaneous condition, only a negative strong correlation emerged between the peak Deceleration and the Empathic Concern subscale (Table 8.2).

Table 8.2. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions.

EXPRESSION	IRI		DD CH	MV CH	TMV% CH	TMDec% CH	DD EB	MA EB	Mdec EB	TMV% EB
Posed	COG	PT	0.545	0.389	0.022	-0.525	**-0.571***	-0.316	-0.360	-0.239
		FS	**-0.712***	**-0.662***	-0.438	-0.322	0.518	-0.084	0.432	0.313
	EMO	EC	-0.161	-0.166	-0.543	**-0.600***	0.049	-0.099	-0.055	-0.255
		PD	**0.571***	**0.612***	0.234	0.184	0.167	0.316	0.364	-0.260
Spontaneous	COG	PT	-0.122	0.003	-0.233	-0.439	-0.213	-0.489	-0.532	-0.162
		FS	0.161	0.034	0.193	-0.464	-0.074	0.116	-0.218	0.255
	EMO	EC	0.448	0.427	0.377	-0.035	0.243	-0.403	**-0.684***	0.065
		PD	-0.114	-0.066	-0.318	0.180	-0.101	-0.385	-0.461	0.033

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,9)}$=19.276, p=0.002, VS-MPR=33.205, η^2_p=0.682) was found. The Distance of the Cheilions from the tip of the nose was wider when the sadness expression was posed than when it was spontaneous (59.231 and 58.306 mm).

None of the remaining parameters was statistically significant (all p_s > 0.05).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,9)}$=5.953, p=0.037, VS-MPR=2.995, η^2_p=0.398) was found. The delta was wider when the sadness expression was posed than when it was spontaneous (2.061 and 0.239 mm).

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,9)}$=15.111, p=0.004, VS-MPR=17.796, η^2_p=0.627) was found. The interaction between Condition and Side of the face was also statistically significant ($F_{(1,9)}$=5.130, p=0.05, VS-MPR=2.463, η^2_p=0.363). Post hoc comparisons revealed that posed expressions of sadness performed in the Left side of the face had a higher Acceleration peak than spontaneous expressions performed in the Right side of the face (p=0.009). Crucially, in the Left side of the face, posed expressions of sadness had a higher Acceleration peak than spontaneous expressions (p=0.009; Figure 8.3).

Maximum Deceleration (MDec) | A significant main effect of the Condition ($F_{(1,9)}$=12.855, p=0.006, VS-MPR=12.180, η^2_p=0.588) was found. The Deceleration peak was higher when the expression of sadness was posed than when it was spontaneous (352.887 and 51.53 mm/sec^2).

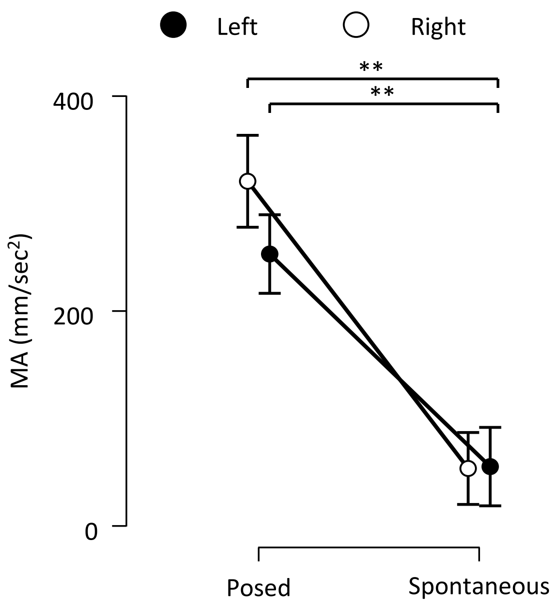

Figure 8.3. The graph shows the Maximum Acceleration (MA) reached by the Left and Right Eyebrows occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01).

INTERIM DISCUSSION – EXPERIMENT 2

Proximal movements

In Experiment 2, Linear Mixed-effects Models indicate that the posed expression of sadness in the lower part of the face was performed with greater peak Distance and Velocity, and early peak Velocity and Deceleration than the spontaneous expression. In the upper part of the face, I found a consistency with Experiment 1 in both Acceleration and Deceleration parameters. Posed expressions induced by Motor Contagion, moreover, were characterized by higher peak Distance and earlier peak Velocity.

IRI

For the Posed condition, spatial (DD), temporal (TMDec%), and speed (MV) measures showed strong negative correlations with the Fantasy subscale and the Empathic Concern subscales. In addition, a positive correlation was found between peak Velocity and the subscale of Personal Distress. During spontaneous expressions of sadness, the peak Deceleration between the eyebrows was negatively correlated with the Empathic Concern subscale.

Distal movements

The repeated-measures ANOVA on distal movements showed a significant main effect of the Condition for the spatial and speed parameters of movement. Posed expressions showed a greater Distance in both the lower and upper part of the face (i.e., corners of the mouth pulled down and Eyebrows pulled up) and an increased peak Deceleration of the Eyebrows than spontaneous expressions. Moreover, the peak Acceleration of the Left Eyebrow was higher during the Posed than the Spontaneous condition.

Motor Contagion

As concern the horizontal axis, the results showed greater and earlier spatial, speed and temporal parameters during posed than spontaneous expressions, both in the lower and upper part of the face. These results from a Motor Contagion paradigm show that also the contribution of the lower part of the face is crucial for distinguishing posed and spontaneous expressions of sadness, as suggested by Ross and colleagues (2016).

Along the vertical axis, a crucial difference emerged in the upper part of the face: the peak Acceleration of the Left Eyebrow was higher during posed than spontaneous expressions. This result on the lateralization of posed expressions following Motor Contagion does support the three main Hypotheses on emotional lateralization (see Ross et al., 2019).

Comparison analysis – Experiment 1 vs. 2

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Delta Distance (DDCH) | A significant main effect of Condition was found ($F_{(1, 11)}$=5.376, p=0.041, VS-MPR=2.824, η^2_p=0.328). Posed expressions had a wider range than spontaneous expressions of sadness (0.824 and 0.322 mm, respectively).

Maximum Velocity (MVCH) | A significant main effect of Condition was found ($F_{(1, 11)}$=5.473, p=0.039, VS-MPR=2.897, η^2_p=0.332). Posed expressions had a higher peak Velocity than spontaneous expressions of sadness (8.363 and 3.396 mm/sec, respectively).

Upper part of the face – Eyebrows (EB)

Delta Distance (DDEB) | A significant main effect of Condition was found ($F_{(1, 11)}$=5.558, p=0.038, VS-MPR=2.962, η^2_p=0.336). Posed expressions had a wider range than spontaneous expressions of sadness (3.497 and 0.166 mm/sec, respectively).

Maximum Acceleration (MAEB) | A significant main effect of Condition was found ($F_{(1, 11)}$=14.393, p=0.003, VS-MPR=21.254, η^2_p=0.567). Posed expressions had a higher Acceleration peak than spontaneous expressions of sadness (402.600 and 65.536 mm/sec^2, respectively).

Maximum Deceleration (MDecEB) | A significant main effect of Condition was found ($F_{(1, 11)}$=9.473, p=0.011, VS-MPR=7.683, η^2_p=0.463). Posed expressions had a higher Deceleration peak than spontaneous expressions of sadness (449.153 and 61.270 mm/sec^2, respectively).

Mixed ANOVA: Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | The main effect of Condition was significant ($F_{(1,11)}$=31.433, p<0.001, VS-MPR=264.880, η^2_p=0.741). Posed expressions had greater mouth widening than spontaneous expressions (58.262 and 57.080 mm, respectively).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | The main effect of Condition was significant ($F_{(1,11)}$=5.154, p=0.044, VS-MPR=2.665, η^2_p=0.319). Posed expressions had an increased range of eyebrow raising than spontaneous expressions (1.837 and 0.167 mm, respectively).

Maximum Acceleration (MA) | The main effect of Condition was significant ($F_{(1,11)}$=15.718, p=0.002, VS-MPR=27.158, η^2_p=0.588). Posed expressions had a higher Acceleration peak of eyebrow raising than spontaneous expressions (266.608 and 38.302 mm/sec^2, respectively).

Maximum Deceleration (MDec) | The main effect of Condition was significant ($F_{(1,11)}$=9.705, p=0.010, VS-MPR=8.095, η^2_p=0.469). Posed expressions had a higher Deceleration peak of eyebrow raising than spontaneous expressions (290.497 and 38.559 mm/sec^2, respectively).

Interim Discussion – Comparison Analysis

Results from two Experiments demonstrated that both proximal and distal facial movements provide relevant details to characterize and distinguish between spontaneous and posed expressions of sadness.

Proximal movements

The mixed ANOVA on the two experiments did not reveal any effect of the Experiment factor on kinematics. Only the main effect of Condition emerged. This analysis again confirmed that posed expressions of sadness were characterised by higher spatial and speed parameters compared to spontaneous expressions, both in the upper and lower part of the face.

Distal movements

Similar to the results obtained on proximal movements, no effect of the Experiment factor emerged on the kinematics of distal movements. Only the main effect of Condition was shown. The Posed condition required more distal movements than the Spontaneous condition in both the upper and lower part of the face: the corners of the mouth were pulled down and the Eyebrows were pulled up. In addition, the Posed condition was characterised by a higher peak Acceleration of the Eyebrows.

Emotional vs. Motor Contagion

Along the horizontal axis, the results confirmed a contribution of both the upper and lower parts of the face in distinguishing between posed and spontaneous expressions of sadness. This result is interesting in that it finds confirmation in the research of Ross and colleagues (2016) and in the more recent study of Kastendieck and colleagues (2022).

Along the vertical axis there were no differences on lateralization, either in the upper part or in the lower part of the face.

9 | Experimental Chapter 6:

Fear

Fear is an emotion usually induced by a dangerous or threatening stimulus. It is probably the emotion with the highest physiological and behavioural involvement as it can induce physiological reactions of attack or flight (Öhman, 2002).

On a physiological level, a fear response involves respiratory hyperventilation, increased heart rate, peripheral vasoconstriction of blood vessels, cephalic vasodilation, increased muscle tension, piloerection, dyspepsia, increased blood leucocytes, etc. (Kozlowska et al., 2015).

According to FACS (Ekman et al., 1982; Ekman & Friesen, 1978), in the facial expression of fear the eyebrows are raised upwards or in a horizontal line, the upper eyelids are raised, the eyes are pulled wide opened, the mouth is pulled back a bit and may open slightly but has tension in the lips that flex outwards. Fear and surprise may appear similar, but the lip pulls back and the mouth falls open a bit in the expression of fear, whereas the lips do not pull back and the mouth opens wide in the expression of surprise (Cacioppo & Cacioppo, 2020).

The facial expression of fear has a high adaptive value both for the person experiencing it, facilitating a defensive response to danger, and for the person observing it, who is warned of potential danger (Öhman, 2002).

However, despite the fact that there is a practically infinite number of studies that have studied fear at a cerebral level, very few studied the facial expression related to this emotion (Bologna et al., 2016).

Experiment 1

Methods

Participants

Eleven participants (10 females and 1 male) aged between 23 and 28 years ($Mean_{age}$=24.800, SD=1.932) out of 20 were analysed. The remaining participants were excluded due to poor registration for face tracking (N=8) or technical/recording problems (N=2).

Stimuli and Procedure

For the Posed condition I adopted a static picture of fear. Spontaneous fear was instead elicited by using video clips inducing emotional contagion.

Results

Linear Mixed Effect Models: Posed vs. Spontaneous Proximal Movements

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with a decrease of all the spatial and speed parameters when the participants performed a posed expression of fear, compared to when they displayed anger (MDCH: $F_{(1,10)}$=13.008, p=0.005, VS-MPR=14.367; DDCH: $F_{(1,10)}$=21.954, p<0.001, VS-MPR=292.177; MVCH: $F_{(1,10)}$=27.854, p<0.001, VS-MPR=129.247; MACH: $F_{(1,10)}$=19.531, p<0.001, VS-MPR=169.111; MDecCH: $F_{(1,10)}$=34.469, p<0.001, VS-MPR=3309.207; Figure.). None of the temporal parameters revealed significant differences through conditions (all p_s > 0.05).

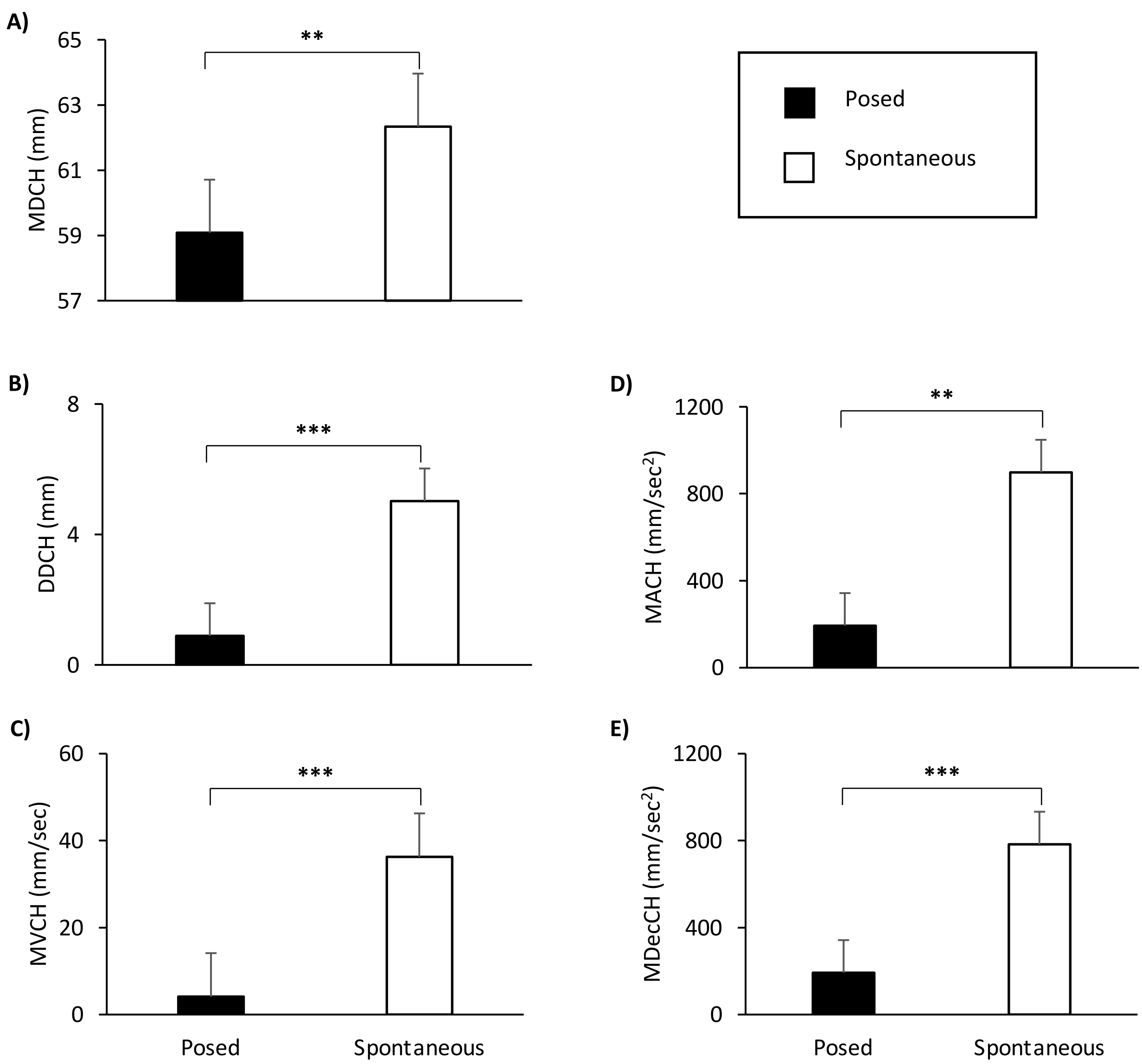

Figure 9.1. Graphical representation of spatial and speed components of movement during posed and spontaneous expressions of fear. Lower part of the face: (A) Maximum Distance (MDCH); (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH), (D) Maximum Acceleration (MACH), (E) Maximum Deceleration (MDecCH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01; ***= p<0.001).

Upper part of the face – Eyebrows (EB)

Linear Mixed-effects Models did not reveal a significant effect in the upper part of the face. The spatial, Velocity and temporal parameters were not statistically significant (all $p_s > 0.05$).

Correlations between IRI and kinematics measures

Strong correlations emerged only in the lower part of the face (i.e., Cheilion markers) and only in the Emotional scale for the Posed condition. In particular, positive correlations were found between the Empathic Concern subscale and Acceleration and Deceleration peaks , and a negative correlation emerged between the Personal Distress subscale and Delta Distance (Table 9.1).

Table 9.1. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions.

EXPRESSION	IRI		MD CH	DD CH	MV CH	MA CH	MDec CH
Posed	COG	PT	0.470	0.462	-0.297	-0.013	0.444
		FS	0.243	0.039	-0.025	-0.291	0.223
	EMO	EC	0.365	-0.241	-0.035	**0.613** *	**0.615** *
		PD	0.029	**-0.600** *	0.256	0.332	0.178
Spontaneous	COG	PT	0.260	-0.274	-0.194	-0.397	-0.256
		FS	0.156	-0.210	-0.458	-0.183	-0.247
	EMO	EC	0.161	-0.126	-0.347	-0.237	0.130
		PD	-0.144	-0.294	-0.460	-0.266	-0.144

Repeated-measures ANOVA: Posed vs. Spontaneous Distal Movements

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) A significant main effect of the Condition ($F_{(1,10)}$=9.587, p=0.011, VS-MPR=7.251, η^2_p=0.489) was found. The amplitude was wider when the scared expression was spontaneous than when it was posed.

Delta Distance (DD) A significant main effect of the Condition ($F_{(1,10)}$=44.534, p<0.001, VS-MPR=676.943, η^2_p=0.817) was found. The Delta was wider when the scared expression was spontaneous than when it was posed.

Maximum Velocity (MV) A significant main effect of the Condition ($F_{(1,10)}$=17.079, p=0.002, VS-MPR=29.165, η^2_p=0.631) was found. The Velocity peak was higher when the scared expression was spontaneous than when it was posed.

Maximum Acceleration (MA) A significant main effect of the Condition ($F_{(1,10)}$=16.412, p=0.002, VS-MPR=26.149, η^2_p=0.621) was found. The Acceleration peak was higher when the scared expression was spontaneous than when it was posed.

Maximum Deceleration (MDec) A significant main effect of the Condition ($F_{(1,10)}$=20.945, p=0.001, VS-MPR=52.543, η^2_p=0.677) was found. The Deceleration peak was higher when the scared expression was spontaneous than when it was posed.

Time to Maximum Distance (TMD%) A significant main effect of the Condition ($F_{(1,10)}$=6.897, p=0.025, VS-MPR=3.951, η^2_p=0.408) was found. The Maximum Distance was reached earlier during spontaneous than posed expressions.

Time to Maximum Deceleration (TMDec%) A significant main effect of Side of the face ($F_{(1,10)}$=17.601, p=0.002, VS-MPR=31.712, η^2_p=0.638) was found. The Deceleration peak was reached earlier in the Right than in the Left side of the face (Figure 9.2).

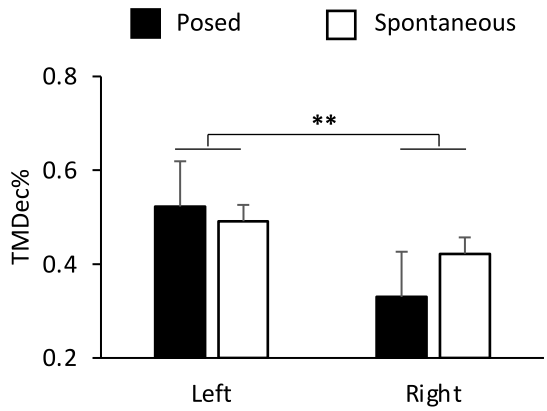

Figure 9.2. Graphical representation of the Time to Maximum Deceleration achieved by the Left and Right Cheilions across conditions (TMDec%). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (**=p<0.01).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Repeated measures ANOVA did not reveal a significant effect in the upper part of the face. The spatial, Velocity and temporal parameters were not statistically significant (all $p_s > 0.05$).

Interim Discussion – Experiment 1

Proximal movements

Results from the Linear Mixed Effects Models on proximal movements of the corners of the mouth indicate that spontaneous expressions of fear were performed with higher peak Distance (absolute and delta values), Velocity, Acceleration, and Deceleration compared to posed expressions. This seems to suggest that while observing a fear scene the Involuntary Pathway specifically activated the lower part of the face but not the upper part.

Distal movements

Results from the repeated-measure ANOVAs on distal movements showed higher peak Distance, Velocity, Acceleration, and Deceleration for posed expressions than for spontaneous expressions at both the Left and Right corners of the mouth. In terms of time, the peak Distance was reached earlier during the Posed than the Spontaneous condition. Moreover, the main effect of Side of the face was found in the temporal parameter of lower face movements. In particular, the time required to reach the peak Deceleration was earlier in the RightCH than in the LeftCH.

Emotional Contagion

Only the lower part of the face proved to be critical in differentiating posed from spontaneous expressions. In particular, the spatial and speed parameters of the corners of the mouth were lower for posed than for spontaneous expressions. None of the spatial, speed or temporal parameters were significant in the upper part of the face for either proximal or distal movements. These results confirm previous findings from Ross and colleagues (2016) who considered the lower part of the face to be particularly informative. According to FACS (Ekman et al., 1982; Ekman & Friesen, 1978), the upper part of the face as well should be involved in fear expression. However, the contribution of the Eyebrows did not emerge with the Emotional Contagion paradigm.

Taking into consideration the hemi-face, along the vertical axis, only one difference emerged. The time at which Maximum Deceleration occurred was earlier in the RightCH than in the LeftCH. This result does not support the three main Hypotheses on emotional lateralization (see Ross et al., 2019).

Experiment 2

Methods

Participants

Twenty participants (16 females and 4 males) aged between 20 and 29 years ($Mean_{age}$=23.429, SD=2.181) were recruited. None of them took part in Experiment 1.

Stimuli and Procedure

The image adopted for the Posed condition was the same as for Experiment 1. Spontaneous fear was instead elicited by using video clips inducing motor contagion.

Validation study

I conducted a preliminary online validation study on Qualtrics with 49 healthy volunteers (36 females, 13 males; age=18-60 years) to select the most appropriate stimuli for the Experiment (for the procedure see Validation Study in General Methods). I selected the three video clips with the highest scores on the Likert and the SAM assessing the arousal, and the lowest scores on the SAM assessing the valence.

RESULTS

LINEAR MIXED EFFECT MODELS: POSED VS. SPONTANEOUS PROXIMAL MOVEMENTS

Lower part of the face – Cheilions (CH)

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of all the spatial and speed parameters when the participants performed a posed expression of fear, compared to when they displayed anger (MDCH: $F_{(1,19)}$=5.434, p=0.030, VS-MPR=3.470; DDCH: $F_{(1,19)}$=8.790, p=0.008, VS-MPR=9.861; MVCH: $F_{(1,19)}$=8.918, p=0.005, VS-MPR=14.350; MACH: $F_{(1,19)}$=6.721, p=0.017, VS-MPR=5.217; Figure 9.3 A-D). None of the temporal parameters revealed significant differences through conditions (all $p_s > 0.05$).

The upper part of the face – eyebrows

The Linear Mixed-Effect Models revealed a significant effect of Condition with an increase of all the spatial parameters when the participants performed a posed expression of fear, compared to when they displayed anger (MDEB: $F_{(1,19)}$=5.407, p=0.031, VS-MPR=3.440; DDEB: $F_{(1,19)}$=14.602, p=0.001, VS-MPR=50.336; Figure 9.3 E-F). Moreover, Velocity peak was reached earlier during posed than spontaneous expressions of fear (TMV%EB: $F_{(1,19)}$=20.04, p=0.036, VS-MPR=3.071; Figure 9.3 G).

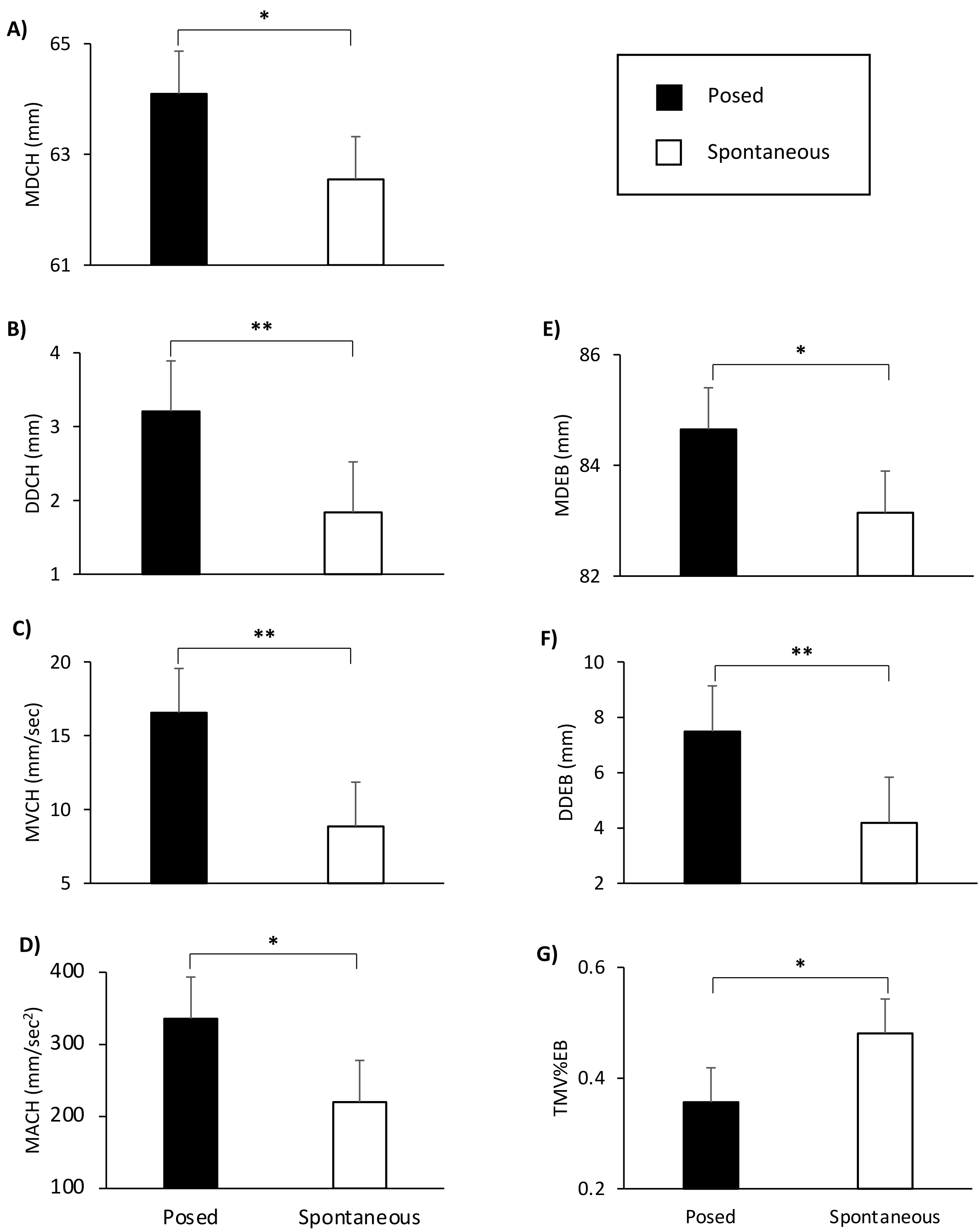

Figure 9.3. Graphical representation of spatial and speed components of movement during posed and spontaneous expressions of fear. Lower part of the face: (A) Maximum Distance (MDCH); (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH); (D) Maximum Acceleration (MACH). Upper part of the face (E) Maximum Distance (MDEB); (F) Delta Distance (DDEB); (G) Time to Maximum Distance (TMV%EB). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*=p<0.05; **=p<0.01).

CORRELATIONS BETWEEN IRI AND KINEMATICS MEASURES

Only a strong positive correlation emerged between the Cognitive Perspective Taking subscale and peak Acceleration for the Posed condition (Table 9.2).

Table 9.2. Pearson's Correlation between IRI and kinematic measures of posed and spontaneous expressions.

EXPRESSION	**IRI**		**MD CH**	**DD CH**	**MV CH**	**MA CH**	**MD EB**	**DD EB**	**TMV% EB**
Posed	COG	PT	0.133	0.226	0.487	**0.558 ***	-0.006	-0.268	0.207
		FS	0.030	0.038	0.096	0.340	-0.089	0.060	-0.368
	EMO	EC	0.231	0.022	0.180	0.498	-0.005	-0.333	0.203
		PD	-0.119	-0.132	0.039	0.142	0.072	-0.538	0.033
Spontaneous	COG	PT	-0.079	-0.176	-0.210	-0.175	-0.232	0.095	0.266
		FS	-0.179	-0.085	0.171	0.238	-0.246	-0.276	0.209
	EMO	EC	0.276	0.003	0.276	0.206	-0.112	-0.105	0.140
		PD	-0.055	0.048	0.299	0.343	-0.236	-0.229	0.178

REPEATED-MEASURES ANOVA: POSED VS. SPONTANEOUS DISTAL MOVEMENTS

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,19)}$=35.705, p<0.001, VS-MPR=4084.059, η^2_p=0.641) and a significant interaction Condition by Side of the Face (MD: $F_{(1,19)}$=5.760, p=0.026, VS-MPR=3.850, η^2_p=0.224) were found. Post hoc contrasts confirmed that a posed expression of fear was wider compared to a spontaneous expression of fear both in the Left and Right sides of the face (all p_s<0.001; Figure 9.4 A).

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,19)}$=19.219, p<0.001, VS-MPR=157.292, η^2_p=0.490) was found. The Delta was wider when the scared expression was posed than when it was spontaneous.

Maximum Velocity (MV) | A significant main effect of the Condition ($F_{(1,19)}$=18.037, p<0.001, VS-MPR=118.869, η^2_p=0.474) was found. The Velocity peak was higher when the scared expression was posed than when it was spontaneous.

Maximum Acceleration (MA) | A significant main effect of the Condition ($F_{(1,19)}$=8.036, p=0.010, VS-MPR=7.842, η^2_p=0.621) was found. The Acceleration peak was higher when the scared expression was posed than when it was spontaneous.

Maximum Deceleration (MDec) | A significant main effect of the Condition ($F_{(1,19)}$=5.783, p=0.026, VS-MPR=3.878, η^2_p=0.224) was found. The Deceleration peak was higher when the scared expression was posed than when it was spontaneous.

Time to Maximum Deceleration (TMDec%) | A significant main effect of Side of the face ($F_{(1,19)}$=5.001, p=0.037, VS-MPR=3.022, η^2_p=0.200) was found. The Deceleration peak was reached earlier in the Right than in the Left side of the face (Figure 9.4 B).

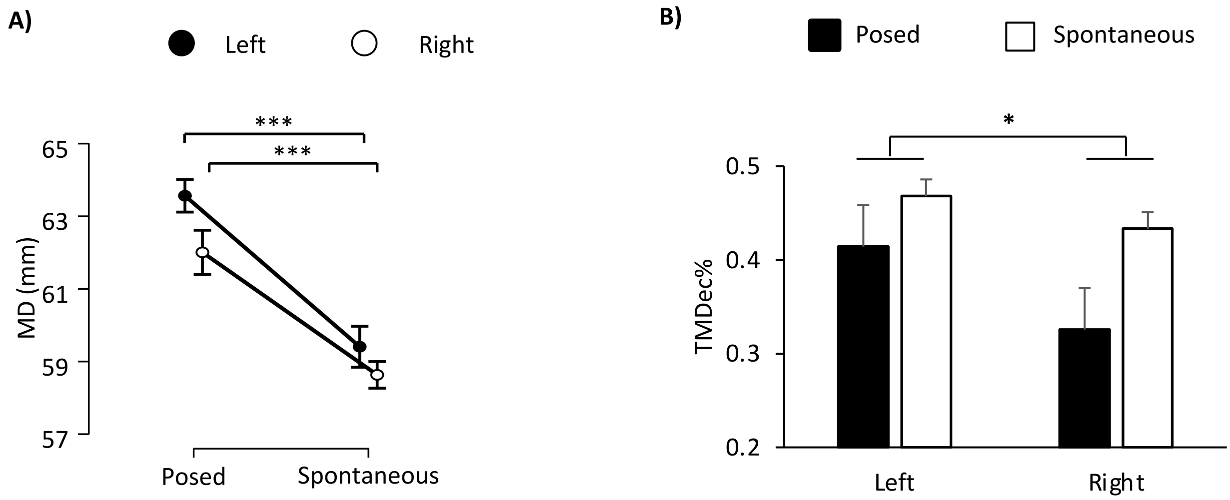

Figure 9.4. The graphs show: (A) the Maximum Distance (MD) and (B) the Time to Maximum Deceleration reached by the Left and Right Cheilions occur across conditions. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*<0.05; ***=p<0.001).

The upper part of the face – eyebrows

Maximum Distance (MD) | A significant main effect of the Condition ($F_{(1,19)}$=5.173, p<0.05, VS-MPR=3.193, η^2_p=0.206) was found. The amplitude was wider when the scared expression was posed than when it was spontaneous.

Delta Distance (DD) | A significant main effect of the Condition ($F_{(1,19)}$=17.389, p<0.001, VS-MPR=101.640, η^2_p=0.465) was found. The Delta was wider when the scared expression was posed than when it was spontaneous.

Interim Discussion – Experiment 2

Proximal movements

In Experiment 2, I found an opposite trend compared to Experiment 1 for proximal movements in both the lower and upper part of the face. In fact, the peak Distance, Velocity and Acceleration of the corners of the mouth were higher in the Posed than in the Spontaneous condition. Moreover, the peak Distance of the Eyebrows was higher, and the peak Velocity was anticipated during posed than spontaneous expressions.

IRI

No strong correlations were found between kinematic measures and IRI subscales.

Distal movements

Here as well I found an opposite trend compared to Experiment 1 in both the lower and upper part of the face for distal movements. In fact, the peak Distance, Velocity, Acceleration and Deceleration of the corners of the mouth were higher in the Posed than in the Spontaneous condition. Moreover, the peak Distance of the Eyebrows was higher during posed than spontaneous expressions. The main effect of Side of the face only emerged for the time parameter (TMDec%). The peak Deceleration was reached earlier in the RightCH compared to the LeftCH.

Motor Contagion

In Experiment 2, where fear was induced with Motor Contagion, I found spatial and speed parameters to be crucial for distinguishing posed from spontaneous expressions both in the lower part of the face - as suggested by Ross and colleagues (2016) and in the upper part of the face – as suggested by the FACS (Ekman et al., 1982; Ekman & Friesen, 1978). Differently from Experiment 1, here the spatial and speed parameters were greater when participants had to voluntarily pose fear expressions. In addition, there was also a temporal parameter sensitive to the different expressions: peak Eyebrow Velocity was earlier in posed than spontaneous expressions, thus corroborating the essential contribution of the upper part of the face as indicated by FACS (Ekman et al., 1982; Ekman & Friesen, 1978).

Taking into consideration the hemi-face, along the vertical axis, a difference emerged. As for Experiment 1, the peak Deceleration was reached earlier in the RightCH than in the LeftCH. This result does not support the three main Hypotheses on emotional lateralization(see Ross et al., 2019).

Comparison analysis – Experiment 1 vs. 2

Mixed ANOVA: Proximal Movements

Lower part of the face – Cheilions (CH)

Maximum Distance (MDCH) | The interaction between Experiment and Condition was statistically significant ($F_{(1,30)}$=18.393, p<0.001, VS-MPR=247.009, η^2_p=0.380). Post hoc comparisons revealed that posed expressions of fear performed in Experiment 1 had a smaller Distance than spontaneous expressions within Experiment (p=0.007). Crucially, posed expressions of fear performed in Experiment 1 had a smaller Distance than posed expression performed in Experiment 2 (p=0.035; Figure 9.5 A).

Delta Distance (DDCH) | A significant main effect of Condition was found ($F_{(1, 30)}$=9.770, p=0.004, VS-MPR=16.939, η^2_p=0.246). The interaction between Experiment and Condition was also statistically significant ($F_{(1,30)}$=37.521, p<0.001, VS-MPR=27068.201, η^2_p=0.556). Post hoc comparisons revealed that, in Experiment 1, posed expressions of fear had a smaller Distance than spontaneous expressions (p<0.001). Moreover, posed expressions of fear performed in Experiment 1 had smaller amplitude than posed expressions performed in Experiment 2 (p=0.014). In addition, spontaneous expression performed in Experiment 1 had wider Distance than spontaneous expression performed in Experiment 2 (p<0.001; Figure 9.5 B).

Maximum Velocity (MVCH) | A significant main effect of Condition was found ($F_{(1,30)}$=21.348, p<0.001, VS-MPR=564.506, η^2_p=0.416). The interaction between Experiment and Condition was also statistically significant ($F_{(1,30)}$=51.302, p<0.001, VS-MPR=385645.939, η^2_p=0.631). Post hoc comparisons revealed that spontaneous expression of fear performed in Experiment 1 had higher peak of speed than all other conditions of Experiments 1 and 2 (all p_s<0.001). Moreover, posed expression of fear performed in Experiment 1 had lower peak of speed compared to the same posed expression of Experiment 2 (p=0.031; Figure 9.5 C).

Maximum Acceleration (MACH) | A significant main effect of Condition was found ($F_{(1,30)}$=20.744, p<0.001, VS-MPR=478.495, η^2_p=0.409). The interaction between Experiment and Condition was also statistically significant ($F_{(1,30)}$=38.525, p<0.001, VS-MPR=33407.103, η^2_p=0.562). Post hoc comparisons revealed that spontaneous expression of fear performed in Experiment 1 had higher peak of Acceleration than posed condition of Experiment 1 and both conditions of Experiment 2 (all $p_s<0.001$; Figure 9.5 D).

Maximum Deceleration (MDecCH) | A significant main effect of Condition was found ($F_{(1,30)}=20.872$, $p<0.001$, VS-MPR=495.616, $\eta^2_p=0.410$). The interaction between Experiment and Condition was also statistically significant ($F_{(1,30)}=41.423$, $p<0.001$, VS-MPR=60338.369, $\eta^2_p=0.580$). Post hoc comparisons revealed that spontaneous expression of fear performed in Experiment 1 had higher peak of Deceleration than posed condition of Experiment 1 and both conditions of Experiment 2 (all $p_s<0.001$; Figure 9.5 E).

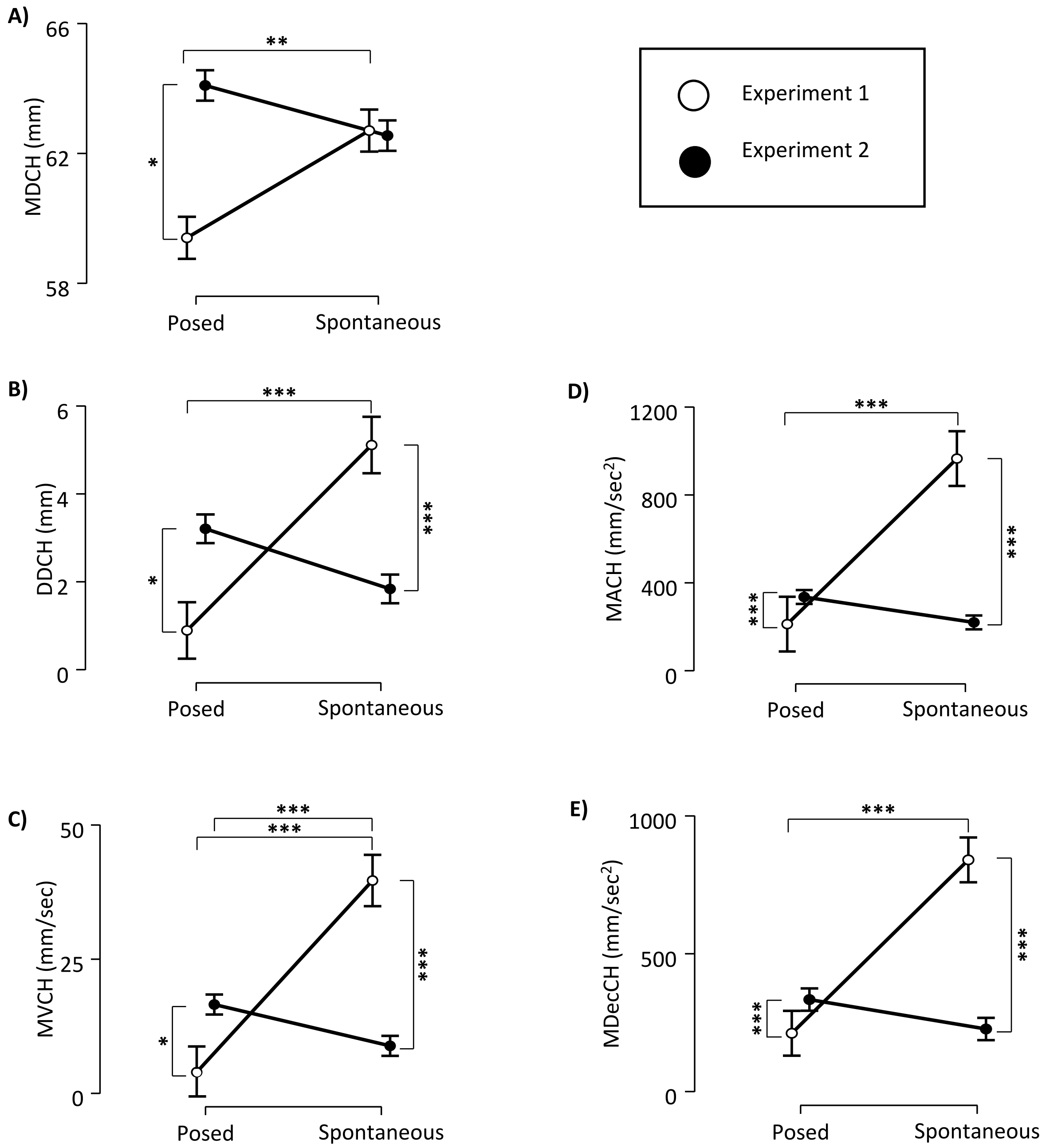

Figure 9.5. The graphs show spatial and speed parameters reached by the Left and Right Cheilions occur across conditions and between Experiment 1 and 2. (A) Maximum Distance (MDCH), (B) Delta Distance (DDCH), (C) Maximum Velocity (MVCH), (D) Maximum Acceleration (MACH), and (E) Maximum Deceleration (MDecCH). Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*<0.05; **=p<0.01; ***=p<0.001).

Upper part of the face – Eyebrows (EB)

Delta Distance (DDEB) | A significant main effect of Condition was found ($F_{(1,30)}$=7.819, p=0.009, VS-MPR=8.728, η^2_p=0.207). Posed expression of fear had wide range of Distance compared to the same expression performed spontaneously (6.149 and 3.996 mm, respectively).

MIXED ANOVA: DISTAL MOVEMENTS

Lower part of the face – Left and Right Cheilions (LeftCH, RightCH)

Maximum Distance (MD) | The 2-way interaction between Condition and Experiment was significant ($F_{(1,30)}$=33.990, p<0.001, VS-MPR=12603.739, η^2_p=0.531). Post hoc comparisons revealed that posed expressions of fear performed in Experiment 2 had wider Distance than posed expression performed in Experiment 1 (p=0.004) and spontaneous expression performed in Experiment 2 (p<0.001; Figure 9.6 A).

Delta Distance (DD) | The 2-way interaction between Condition and Experiment was significant ($F_{(1,30)}$=45.907, p<0.001, VS-MPR=144133.519, η^2_p=0.605). Post hoc comparisons revealed that posed expressions of fear performed in Experiment 1 had smaller Distance compared to: posed expression performed in Experiment 2, spontaneous expression performed in. Experiment 1, spontaneous expression performed in Experiment 2 (all p_s<0.001; Figure 9.6 B).

Maximum Velocity (MV) | A significant main effect of Condition was found ($F_{(1,30)}$=10.053, p=0.003, VS-MPR=18.617, η^2_p=0.251). The 2-way interaction between Condition and Experiment was significant ($F_{(1,30)}$=42.519, p<0.001, VS-MPR=75009.318, η^2_p=0.586). Post hoc comparisons revealed that spontaneous expressions of fear performed in Experiment 1 had higher peak of speed then: the same posed expression performed in Experiment 1 and Experiment 2. Moreover, spontaneous expressions of fear performed in Experiment 1 had also higher peak of speed than spontaneous expression of fear performed in Experiment 2 (all p_s<0.001; Figure 9.6 C).

Maximum Acceleration (MA) | A significant main effect of Condition was found ($F_{(1,30)}$=18.764, p<0.001, VS-MPR=274.724, η^2_p=0.385). The 2-way interaction between Condition and Experiment was significant ($F_{(1,30)}$=36.205, p<0.001, VS-MPR=20452.255, η^2_p=0.547). Post hoc comparisons revealed that spontaneous expressions of fear performed in Experiment 1 had higher peak of Acceleration then: the same posed expression performed in Experiment 1 and Experiment 2. Moreover, spontaneous expressions of fear performed in Experiment 1 had also higher peak of Acceleration than spontaneous expression of fear performed in Experiment 2 (all p_s<0.001; Figure 9.6 D).

Maximum Deceleration (MDec) | A significant main effect of Condition was found ($F_{(1,30)}$=29.847, $p<0.001$, VS-MPR=4877.447, η^2_p=0.499). The 2-way interaction between Experiment and Condition was significant ($F_{(1,30)}$=43.927, $p<0.001$, VS-MPR=98734.287, η^2_p=0.594). Post hoc comparisons revealed that spontaneous expressions of fear performed in Experiment 1 had higher peak of Deceleration then: the same posed expression performed in Experiment 1 and Experiment 2. Moreover, spontaneous expressions of fear performed in Experiment 1 had also higher peak of Deceleration than spontaneous expression of fear performed in Experiment 2 (all $p_s<0.001$; Figure 9.6 E). The 2-way interaction between Side of the face and Experiment was significant ($F_{(1,30)}$=6.049, p=0.02, VS-MPR=4.719, η^2_p=0.168). Post hoc comparisons revealed that the expression of fear performed Experiment 1 in the Right side of the face had lower Deceleration peak than in the Left side (p=0.013). Crucially, the expression of fear performed in the Right side of the face during Experiment 1 had higher Deceleration peak than the same expression in the same side of the face during Experiment 2 ($p<0.001$; Figure 9.6 F).

Time to Maximum Distance (TMD%) | A significant main effect of Condition was found ($F_{(1,30)}$=5.777, $p<0.001$, VS-MPR=4.261, η^2_p=0.166). The Maximum Distance was reach earlier during spontaneous than posed expressions of fear (54.250 and 67.425 %, respectively).

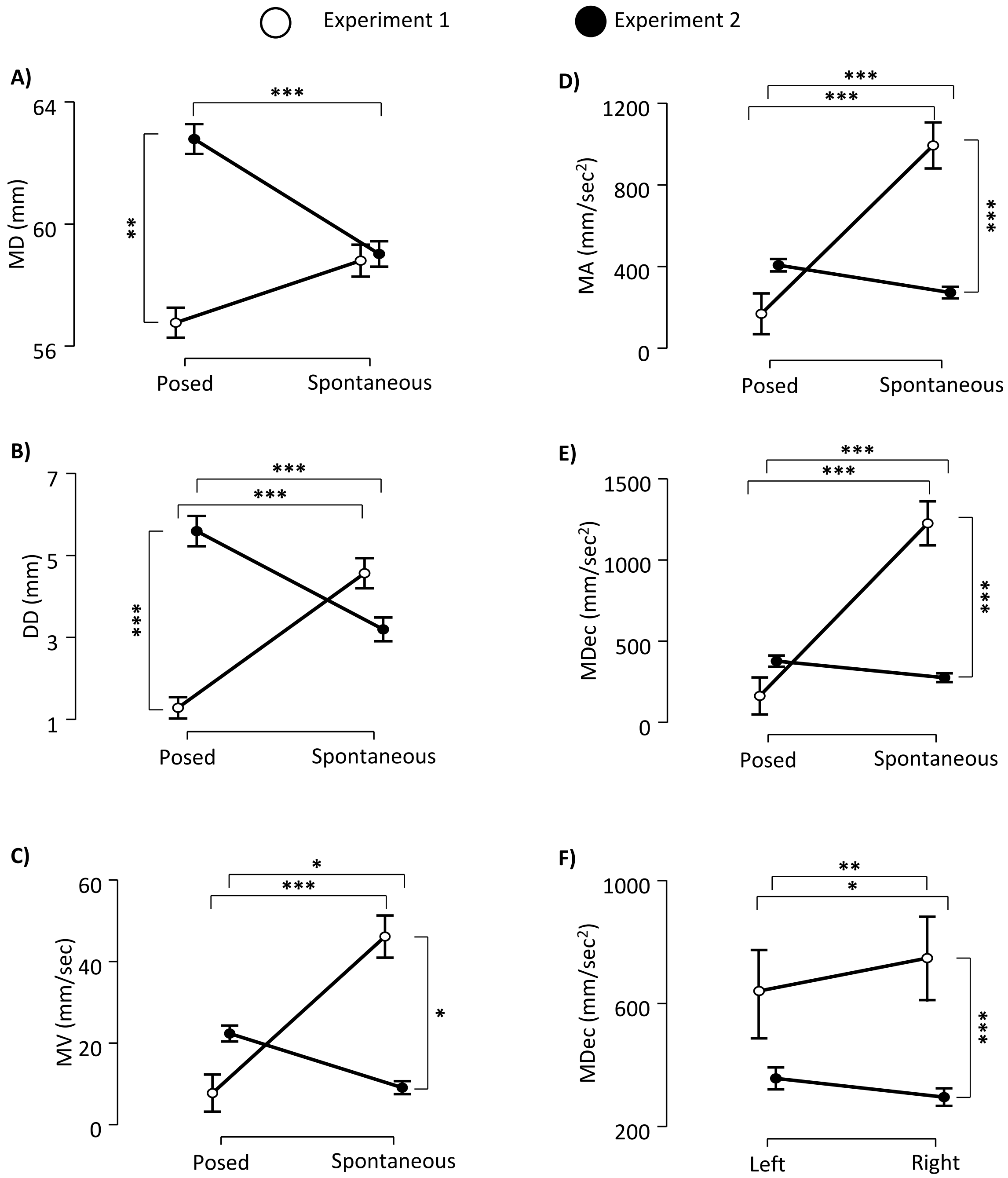

Figure 9.6. The graphs show spatial and speed parameters reached by the Left and Right Cheilions occur across conditions and between Experiment 1 and 2 (A-E). (A) Maximum Distance (MD), (B) Delta Distance (DD), (C) Maximum Velocity (MV), (D) Maximum Acceleration (MA), and (E) Maximum Deceleration (MDec). (F) Two-way interaction Side of the face by Experiment of Maximum Deceleration (MDec) Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*<0.05; **=p<0.01; ***=p<0.001).

Upper part of the face – Left and Right Eyebrows (LeftEB, RightEB)

Delta Distance (DD) | A significant main effect of Condition was found ($F_{(1,30)}$=9.063, p=0.005, VS-MPR=13.348, η^2_p=0.232). Posed expression of fear had wider range Distance than spontaneous expression (3.758 and 2.302 mm, respectively).

Interim Discussion – Comparison Analysis

Results from two Experiments demonstrated and confirmed that facial movements provide relevant and consistent details to characterize and distinguish between spontaneous and posed expressions of fear.

Proximal movements

Mixed ANOVA on the two Experiments revealed that Emotional Contagion (Experiment 1) and Motor Contagion (Experiment 2) had a divergent effect on posed and spontaneous expressions. In particular, spontaneous expressions were characterised by higher peak Distance, Velocity, Acceleration and Deceleration in Experiment 1 than Experiment 2. Whereas posed expressions were characterised by higher peak Distance and Velocity in Experiment 2 than Experiment 1. In other words, when video clips showed scary movies (i.e., Emotional Contagion), the spatial and speed parameters were higher for spontaneous than for posed expressions. Whereas when videos showed truly scared people (i.e., Motor Contagion), posed expressions were characterised by higher spatial and speed parameters than in Experiment 1.

Distal movements

Taking hemiface into consideration, results from the repeated-measure ANOVA on distal movements confirmed and extended all those results by showing also a higher peak Deceleration in the right lower side of the face during Experiment 1 compared to Experiment 2.

Emotional vs. Motor Contagion

Along the horizontal axis, only the lower part of the face was found to be particularly sensitive to distinguish between different types of expressions and different methods of induction (i.e., Emotional vs. Motor Contagion). In particular, posed expressions showed higher spatial and speed parameters in Experiment 2 than Experiment 1. Whereas spontaneous expressions showed higher spatial and speed parameters in Experiment 1 than Experiment 2. Moreover, a speed parameter was also found significant along the vertical axis: the Right corner of the mouth showed a higher peak Deceleration during Experiment 1 compared to Experiment 2.

The induction method had no impact in the upper part of the face. In fact, according to Ross and colleagues (2016), the lower part of the face is more informative than the upper part.

PART 3

MIXED EMOTIONS:

CONTINUOUS EMOTION RATING

10| Experimental Chapter 7:

Continuous Emotion Rating Task

Emotions are not discrete categories, but multi-coloured compositions formed with the contribution of other emotions. This composition may vary depending on the context, age and gender of the participant. When we experience an emotion, it is difficult to categorize it with a single term (e.g., happiness or surprise). It is much more likely that our feeling is a mixture of different emotions.

To study these compositions, I devised and created a new paradigm in which it was possible to view an emotional video and then score our feelings on different Likert scales, one for each of the six basic emotions. This new paradigm highlighted the facets of emotions and the coexistence of multiple emotions with different relative contributions.

Methods

The data were collected at the Neuroscience of Movement Laboratory at the Department of General Psychology - University of Padua. All protocols for containing the epidemiological emergency from COVID-19 were followed (Protocollo Contrasto e Contenimento Virus Sars-CoV-2 adopted by Rector's Decree no. 3093 of 24 September 2020 and subsequent updates).

Participants

A sample of 28 volunteers (18 females and 10 males) aged between 20-29 years ($Mean_{age}$=23.074, SD=2.102) participated in laboratory research. Participants were tested individually and were naïve to the purpose of the research. The experiment was approved by the Ethics Committee of Psychological Research Area 17 of the University of Padua (Protocol N° 3580). In accordance with these ethical principles, the participants, all volunteers, accepted informed consent form for participation in psychology research and personal data processing (Legislative Decree 196/2003; EU GDPR 679/2016).

Stimuli and Procedure

Participants were tested individually in the laboratory. The same eighteen video clips adopted for Experiments 2 (i.e., three for each of the six basic emotions, see Part 2) were used as experimental stimuli. The videos represented people actually experiencing, feeling, and reacting to facts and events, such as eating a disgusting meal for survival or abandoning one's home due to natural disasters that made it uninhabitable. The videos were projected on a screen at a distance of 35 cm from the participant. The dimension of each stimulus was 1024 × 768 pixels displayed on a 22-inch monitor (resolution: 1280 × 1024 pixels, refresh rate 75 Hz, color depth: 32 bits). Each frame was presented in the center of the screen with a black background. The experimental task was designed and run with the use of E-prime software (Psychology Software Tools, version 2.0). Videoclips were divided in three blocks so that each of the six emotions was presented in every block, in pseudorandom order (i.e., to avoid repetitions of the same emotion within and across different blocks). Each video-clip was followed by a series of Self-Reports: six Likert rating scales (minimum=1; maximum=9; with 1= not at all; 9=very) were presented to account for the mixed emotions felt by the participants. I specifically devised a Continuous Emotion Rating task (CER) in which participants had to rate, after watching each video, how happy, surprised, disgusted, angry, sad, and scared they felt. Notably, these labels were not mutually exclusive (e.g., 7 happiness, 4 surprise, “not at all” for the other emotions). Participants also rated valence and arousal through a computerized version of the Self-Assessment Manikin – SAM (Bradley & Lang, 1994; see Part 2 for a description). After viewing each video and completing the CER task and the SAM, participants observed a neutral image chosen from the IASP dataset [1] (1997). This image allowed them to return to a neutral emotional state. The time required for each experiment was approximately 45 minutes.

[1] The International System of Affective Images consists of a large collection of images classified according to their ability to evoke emotions or not. The criteria for classifying images are valence and arousal. Using the manual, 24 images with medium or minimal activation and neutral valence were selected.

DATA ANALYSIS

Data were analyzed using JASP version 0.16 statistical software (JASP Team, 2022). I run the analysis for each emotion separately. There were no missing responses in the dataset. The analyses were divided into three main parts. First, descriptive analyses were conducted on age, gender, and SAM (valence and arousal). Second, - a t-test was run for each category of emotion-inducing videoclips. A significance threshold of $p < 0.05$ was set. Moreover, a repeated measure ANOVA with Condition (Likert ratings for happiness, surprise, disgust, anger, sadness, and fear) as within-subject factor and Gender (female, male) as between-subject factor was perform for the six expressions of emotions. A significance threshold of $p < 0.05$ was set and each p-value obtained was corrected with Bonferroni correction. The partial eta square (η^2_p) value was calculated as an estimate of effect size. In presence of significant interaction, post hoc comparisons were performed. Third, to explore the crosstalk between Likert scores of each emotion, correlations were computed using Pearson correlation coefficient.

RESULTS

Descriptive Statistics

The Median and Mean scores of SAM and CER task across the emotion induced by video clips are reported in Appendix II - Table 1. SE and SD are shown, together with the Minimum and Maximum values assigned.

T-test

I performed paired-samples t-tests on the CER scores of each emotion (see Appendix II - Table 2 for t-values for each video clip) to investigate whether the emotion scores of each reference category differed from the other emotional categories. The video clips inducing happiness, surprise, disgust, and sadness reported statistically significant comparisons (all p_s<0.001). Whereas in the video clips that induced anger, the comparison between the Likert ratings for Anger and Disgust was not statistically significant (p=0.118). Moreover, in the video clips that induced fear, the comparison between the Fear and Surprise Likert scores was not significant (p=0.400) (Appendix II - Table 2).

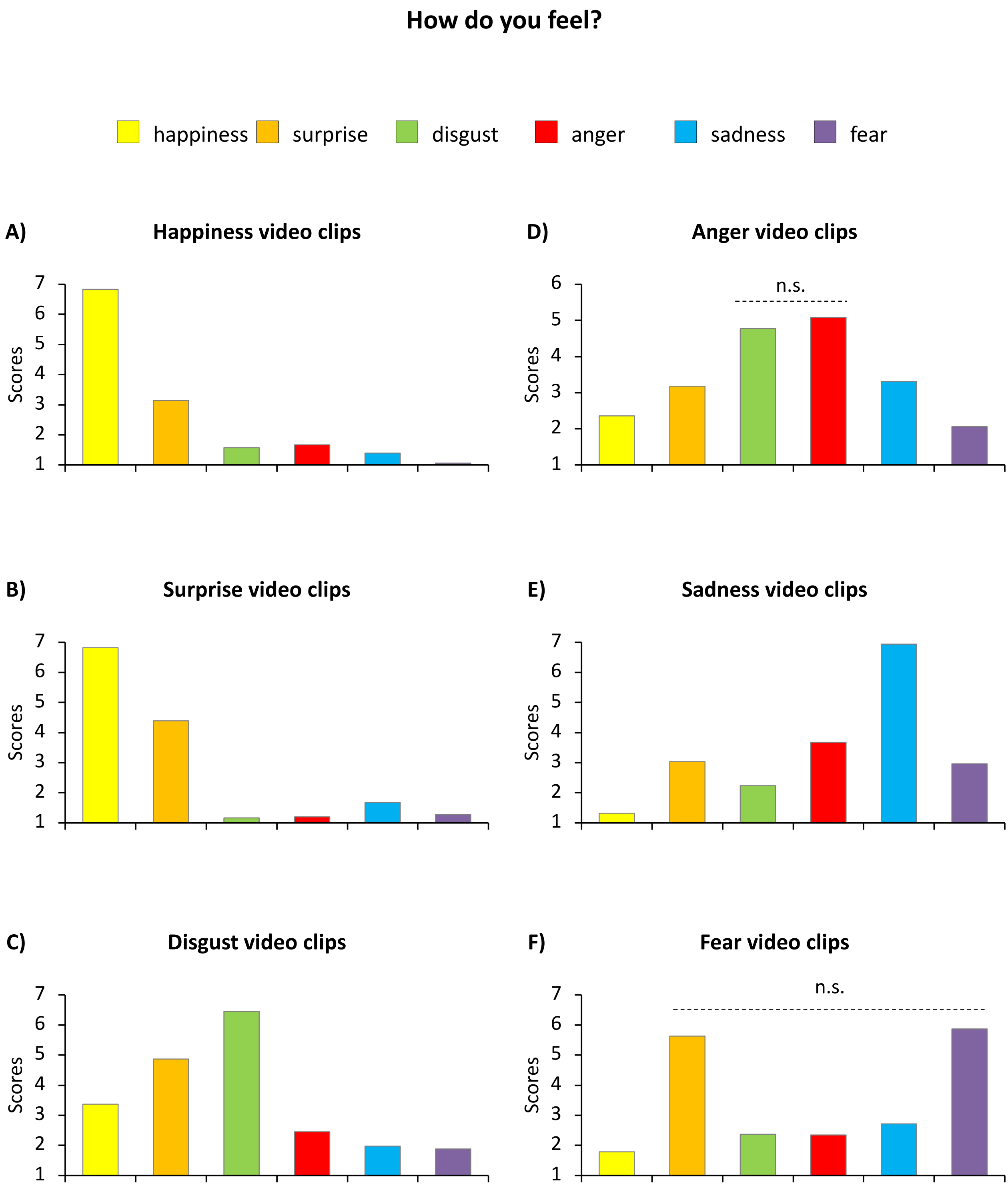

Figure 12.1. Histograms of the Likert scores divided by videoclip categories. The dotted lines indicate the non-significant comparisons (n.s.=p>0.05).

Repeated measures ANOVA

Happiness video clips

The rmANOVA on happiness videoclips showed a main effect of the condition ($F_{(2.299)}$=131.963, p<0.001, VS-MPR=3.051+21, η^2_p=0.830, Greenhouse-Geisser correction). *Post hoc* comparisons reveal that Happiness Likert was higher compared to all other Likert scales (all p_s < 0.001). No significant differences emerged between males and females.

Surprise video clips

The rmANOVA on surprise videoclips through CER task showed a main effect ($F_{(2.299)}$=131.963, p<0.001, VS-MPR=4.056e+23, η^2_p=0.858, Greenhouse-Geisser correction). *Post hoc* comparisons reveal that Surprise Likert was higher compared to all other Likert scales (all p_s < 0.001). No significant differences emerged between males and females.

Disgust video clips

The rmANOVA on disgust videoclips showed a main effect ($F_{(5)}$=37.579, p<0.001, VS-MPR=6.484e+20, η^2_p=0.591). *Post hoc* comparisons reveal that ratings on the Likert for disgust were higher compared to all other Likert ratings (all p_s<0.05). The analysis revealed a significant interaction of CER task by Gender ($F_{(5)=}$5.733, p<0.001, VS-MPR=477.828, η^2_p=0.181). *Post hoc* contrasts showed that after seeing disgusting video clips females reported higher scores for disgust than for happiness (females: Disgust Likert=7.035 and CER-happiness=2.684; p<0.001). Furthermore, females reported lower scores for happiness than males (CER-happiness: males=4.815 and females=2.684; p<0.05; Figure 12.2).

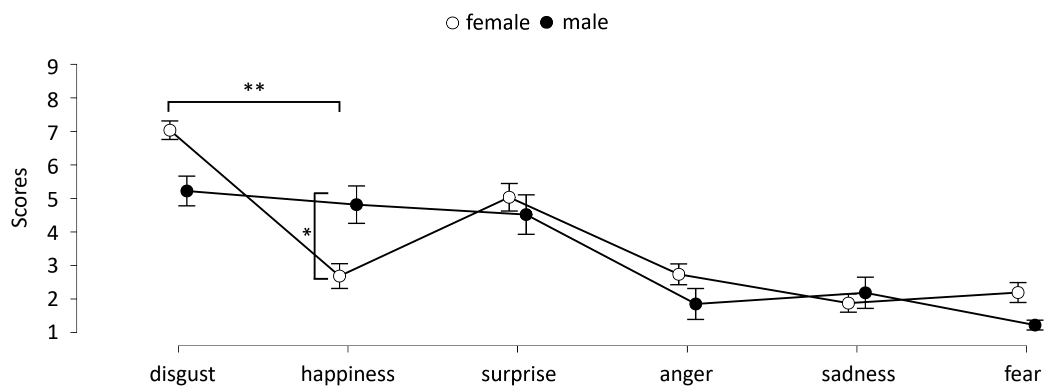

Figure 12.2. The graph shows the scores of CER task by gender. Error bars represent Standard Error. Asterisks indicate statistically significant comparisons (*<0.05; **=p<0.001).

Anger video clips

The rmANOVA on anger videoclips through CER task showed a main effect ($F_{(3.492)}$=19.522, $p < 0.001$, VS-MPR=2.077e+8, η^2_p=0.420, Greenhouse-Geisser correction). Results are graphically summarized in Figure 12.3. *Post hoc* comparisons reveal that Anger Likert was higher compared to all other Likert scales ($p_s < 0.001$) except for Disgust Likert (p=1.000). No significant differences emerged between males and females.

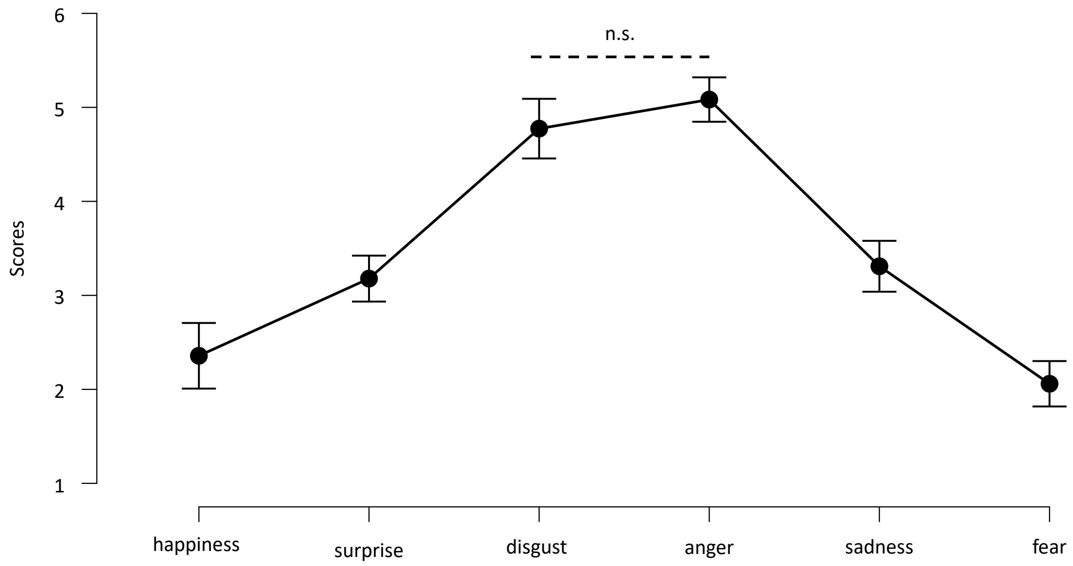

Figure 12.3. The graph shows the scores of CER task. Anger and disgust have a ceiling effect, furthermore, the scores do not differ. Error bars represent Standard Error. The dotted line indicates the only comparison found to be non-significant (n.s. p=1.000).

Sadness video clips

The rmANOVA on sadness videoclips through CER task showed a main effect ($F_{(5)}$=67.274, $p < 0.001$, VS-MPR=8.074e+31, η^2_p=0.714). *Post hoc* comparisons reveal that Anger Likert was higher compared to all other Likert scales (all $p_s < 0.001$). No significant differences emerged between males and females.

Fear video clips

The rmANOVA on fear videoclips through CER task showed a main effect ($F_{(5)}$=52.016, $p < 0.001$, VS-MPR=7.131e+26, η^2_p=0.658). Results are graphically summarized in Figure 12.4. *Post hoc* comparisons reveal that Anger Likert was higher compared to all other Likert scales ($p_s < 0.001$) except for Surprise Likert (p=1.000). No significant differences emerged between males and females.

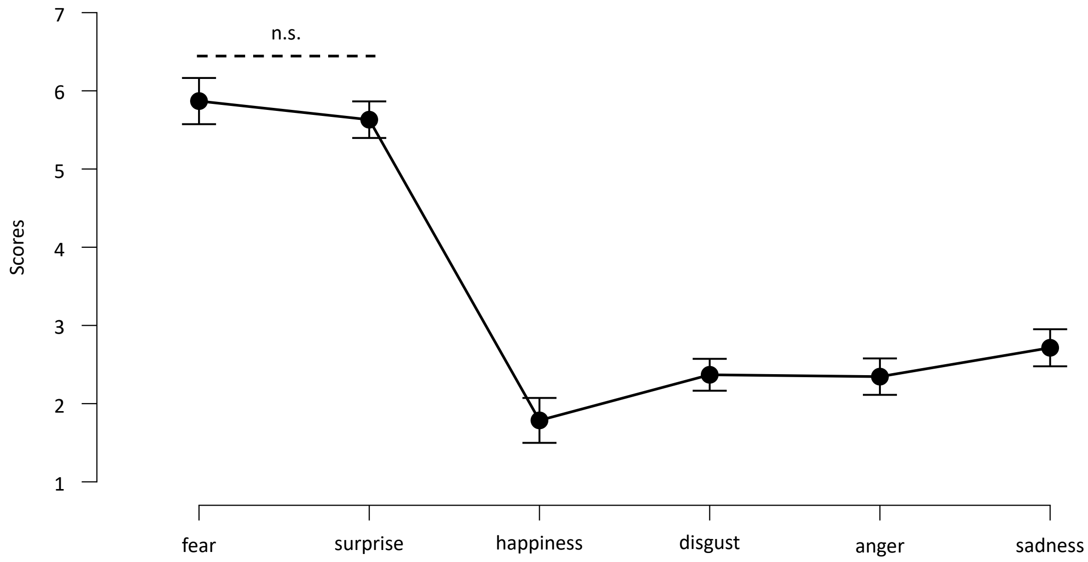

Figure 12.4. The graph shows the scores of CER task. Fear and surprise have a ceiling effect, furthermore, the scores do not differ. Error bars represent Standard Error. The dotted line indicates the only comparison found to be non-significant (n.s. p=1.000).

Correlations across CER scores

Happiness video clips

When correlating the CER scores of happiness and CER scores of the other emotions, **negative** correlations emerged with disgust, anger (r=-0.559; r=-0.561, respectively; all $p_s<0.001$; Figure 12.5 First column). A very strong positive correlation emerged between disgust and anger (r=0.908). Two positive correlations were shown between sadness and disgust; sadness and anger (r=0.616; r=0.679, respectively)

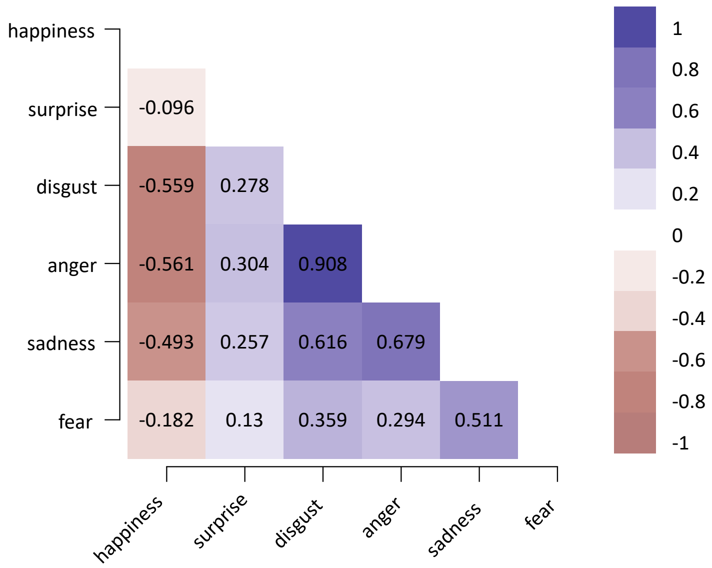

Figure 12.5. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to happiness video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

Surprise video clips

When correlating the CER scores of surprise and CER scores of the other emotions, weak **positive** correlations emerged with happiness, and fear (r<0.5; Figure 12.6 first column). A very strong positive correlation emerged between disgust and anger (r=0.817; Figure 12.6).

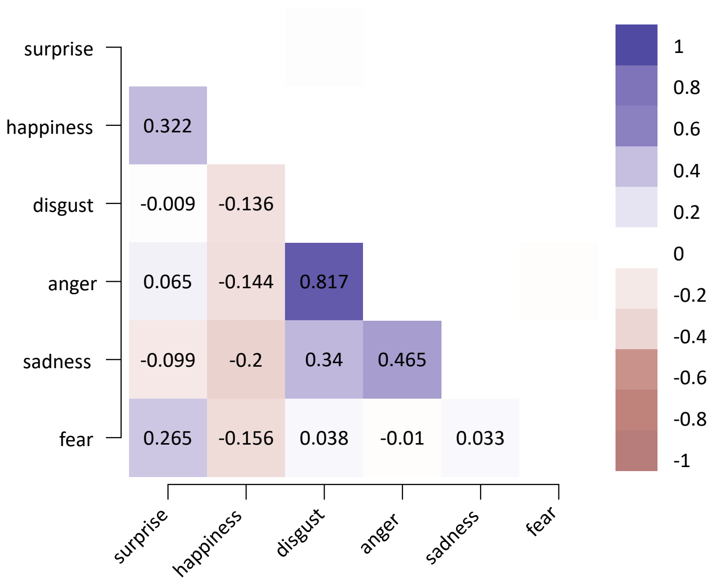

Figure 12.6. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to surprise video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

Disgust video clips

When correlating the CER scores of disgust and CER scores of the other emotions, weak **positive** correlations emerged with surprise, anger, sadness, and fear (all r_s<0.5; Figure 12.7 first column). Moreover, **negative** correlation emerged between disgust and happiness (r=-0.579; Figure 12.7 first column).

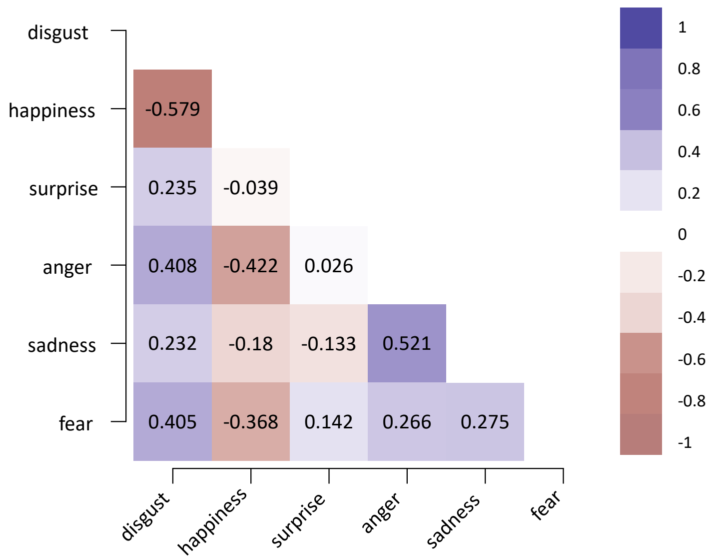

Figure 12.7. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to disgust video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

Anger video clips

When correlating the CER scores of anger and CER scores of the other emotions, **positive** correlations emerged between anger and disgust (r=0.726; Figure 12.8 first column).

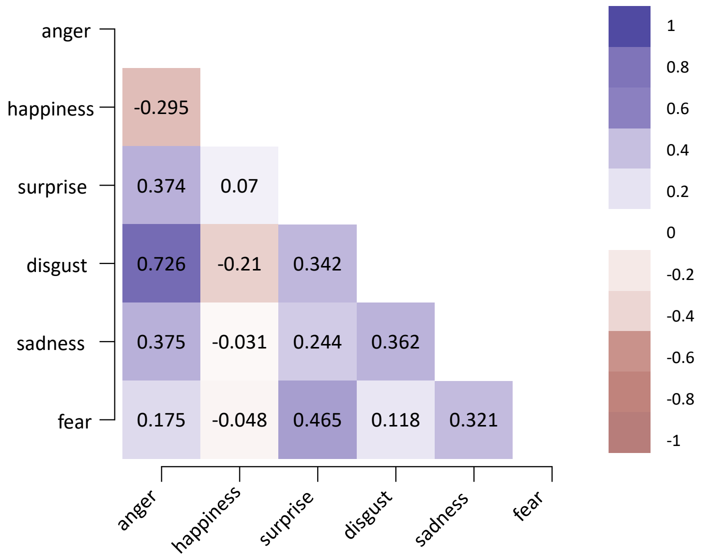

Figure 12.8. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to anger video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

Sadness video clips

When correlating the CER scores of sadness and CER scores of the other emotions, weak correlation was found (all r<0.05). Positive correlation emerged between disgust and anger (r=0.554; Figure 12.9).

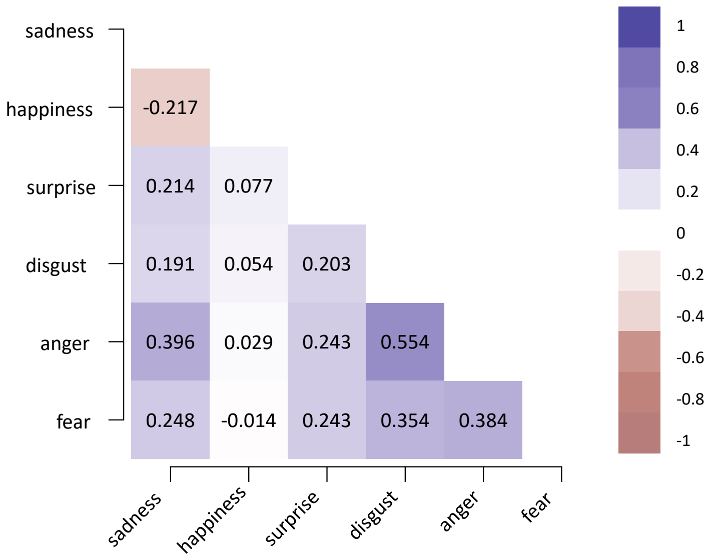

Figure 12.9. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to sadness video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

Fear video clips

When correlating the CER scores of fear and the CER scores of the other emotions, weak correlations emerged (all r<0.5). A weak positive correlation is shown between disgust and anger (r=0.536; Figure 12.10).

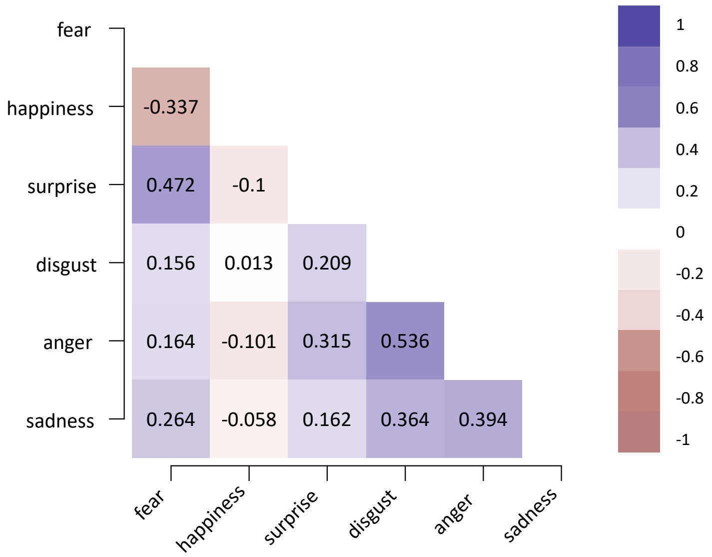

Figure 12.10. Heatmap of the Pearson correlation coefficient matrix showing pairwise correlations between CER scores referring to fear video clips. The blue colour range shows positive correlations, and the brown shows negative correlations.

In addition, to graphically represent the relative values of all six emotions, for each video clip category, I calculated the proportion of each emotion as a percentage (Figure 12.11). For instance, happy videos were rated with 7 points happiness, 3 points surprise, 2 points anger and disgust, 1 point sadness and fear. In percentage terms, if the total was 100, this corresponds to 43% happiness, 20% surprise, 37% all other emotions.

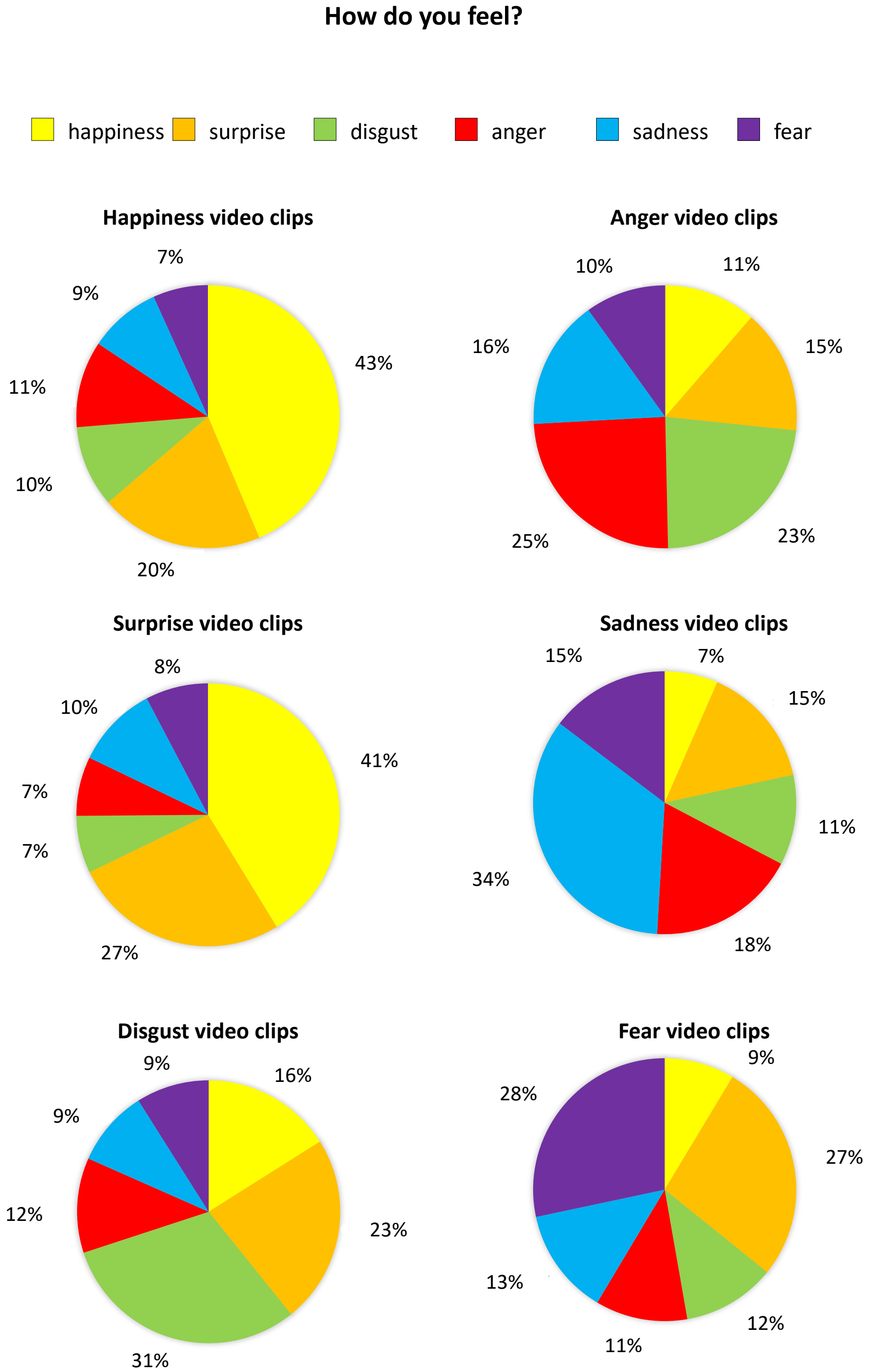

Figure 12.11. Pie charts of the relative scores of CER divided by videoclip categories.

DISCUSSION

The histograms for the Likert data of each emotion show the contribution of different emotions. Interestingly, in the anger videos, the Likert scores of the emotions anger and disgust did not differ. Similarly, in the fear videos, the Likert scores of surprise and fear were similar. A more in-depth investigation was done through the repeated measures ANOVA. For each video clip, an analysis was performed between the Likert scores of each emotion. The results were identical to those of the previous analysis. Furthermore, with the idea of investigating possible differences between males and females, gender was introduced as a between-subject component. In the expression of disgust, a difference emerged on the Likert scale of happiness. It seems that males compared to females felt a kind of amusement when watching particularly disgusting videos.

Finally, to explore the crosstalk between the Likert scores of each emotion, I performed the correlation analysis. The results showed strong correlations between disgust and anger while watching all video clips except those identified to induce disgust and fear. In addition, when watching the happiness video clips, two strong negative correlations emerged: between happiness and disgust and between happiness and anger. Finally, during the disgust video clips, a strong negative correlation emerged between happiness and disgust.

Part 4:

General Discussion

Today, 150 years after the release of Darwin's landmark book “The Expression of the Emotions in Man and Animals” (Darwin, 1872), scientists' conclusions about the expression of emotions are still debated. In each emotion expressions there is a wide degree of variability due to the involvement of different muscles at different times and with different intensities. This variability is due to people's ability to modulate their emotional expressions voluntarily and involuntarily, thus increasing the degree of complexity.

In two series of six kinematic experiments, using a novel method to study the expression of emotions in kinematics, I demonstrated the crucial role of the parameters of space, time, and speed in distinguishing between a spontaneously expressed emotion and the same emotion in pose. In the first series, I made use of a valid and widely used inductive method: Emotional Contagion (See the Interim Discussion of each Chapter for the kinematic details of each expression).

First set of experiments – Emotional Contagion

Posed vs. Spontaneous

In the lower part of the face, spatial parameters of the corners of the mouth are crucial for distinguishing spontaneous from posed expressions of all the emotions, except sadness in which I only found that Cheilions were pulled down during posed expressions. Speed parameters are also useful measures for distinguishing these two types, except for expressions of disgust and sadness. Finally, temporal parameters seem to be specifically relevant only for the expressions of surprise, anger, and fear.

Movements of the upper part of the face also help to distinguish, albeit to a small degree, spontaneous expressions from posed ones. Spatial parameters of the Eyebrows markers characterize posed and spontaneous expressions of happiness and anger, while speed parameters differentiate expressions of anger and sadness.

Interestingly, while kinematic differences between posed and spontaneous expressions of happiness, surprise, anger, sadness, and fear are reliably and consistently detected by spatial and speed parameters – even temporal parameters in the case of fear, it appears that the posed expression of disgust is much more difficult to reveal. Only greater narrowing of the corners of the mouth can reveal an expression of disgust performed on command from a spontaneous reaction.

Left vs. Right

As concerns the comparison between the Left and Right Sides of the face, spatial and speed parameters of the lower part of the face did not show lateralized results - except the peak Distance and Deceleration of the corners of the mouth during expressions of surprise. Indeed, the Right corner of the mouth was more distal than the Left corner during posed expressions and compared to spontaneous expressions. This was in fact the only significant interaction between Condition and Side of the face I found in Experiment 1. At the same time, peak Deceleration was higher on the Left than on the Right side of the face for both types of surprised expressions.

The contribution of temporal parameters, on the other hand, seems to be crucial in detecting differences in the Left and Right sides of emotional expressions. In particular, peak Deceleration of Left Cheilion was delayed with respect to the Right Cheilion during expressions of happiness, surprise, and fear. While peak Distance was anticipated in the Left than in the Right Cheilion during expressions of disgust.

Movements of the upper part of the face, instead, did not show lateralized results – except the peak Distance and Acceleration of the Left Eyebrow during expressions of disgust, that was larger and anticipated than the Right Eyebrow.

Overall, these results confirm that Emotional Contagion is a valid method to induce emotional expressions. In addition, activating the Voluntary Pathway on command to perform a posed expression influenced the lower part of the face more than the upper part. Indeed, expressions of surprise, disgust, and fear were only modulated in the lower part of the face. These results, obtained with an Emotional Contagion paradigm, do not support theories that suggested a crucial role of key movements in the upper part of the face to differentiate posed and spontaneous expressions (Ekman & Friesen, 2003; Namba et al., 2021).

In terms of lateralization, only disgust showed a main effect of the Side in both the upper and lower parts of the face, while expressions of happiness, surprise, and fear showed an effect only in the lower part. Interestingly, expressions of anger and sadness did not show lateralised results. This could be due to the fact that they rely mainly on movements of the upper part of the face, which are innervated bilaterally (see Figure 2.1).

SECOND SET OF EXPERIMENTS – MOTOR CONTAGION

Posed vs. Spontaneous

In the lower part of the face, both spatial and speed parameters of the corners of the mouth are crucial measures for distinguishing posed from spontaneous expressions. In addition, even temporal parameters are more decisive to differentiate expressions of happiness, surprise, anger, and sadness than in Experiment 1.

In the upper part of the face, spatial parameters distinguish posed from spontaneous expressions for all the emotions. Speed parameters also distinguish posed from spontaneous expressions for all the expressions, except happiness and fear. Furthermore, temporal parameters are also crucial in characterising expressions of surprise, disgust, anger, and fear.

Left vs. Right

As concerns the comparison between the Left and Right Side of the face, in the lower part of the face, spatial and speed parameters did not show lateralized results - except the Velocity and Deceleration peaks during surprise. In particular, the results showed higher peaks of the Left with respect to the Right Cheilion. The contribution of temporal parameters was present in the expressions of surprise, disgust, and fear.

During the expression of anger, a significant interaction emerged for the Deceleration peak. The RightCH was more distal during posed than spontaneous expressions. Crucially, during posed expressions of happiness, the LeftCH showed an earlier peak Acceleration and delayed peak Deceleration with respect to the RightCH.

Movements of the upper part of the face showed two relevant interactions between Condition and Side of the face. In particular, during posed expression of sadness, the Left Eyebrow reached higher peak Acceleration than the Right Eyebrow. Moreover, during spontaneous expression of anger, the Left Eyebrow reached the peak distance later than the Right Eyebrow.

Overall, these results confirm that Motor Contagion is a valid method to induce emotional expressions. In addition, the results showed that activating the Voluntary Pathway on command to perform a posed expression influenced the lower part of the face more than the upper part. Indeed, all expressions were modulated both in the lower part of the face. These results, obtained with a Motor Contagion paradigm, partially support theories that suggested a crucial role of key movements in the upper part of the face to differentiate posed and spontaneous expressions (Ekman & Friesen, 2003; Namba et al., 2021). Interestingly, expressions of anger and sadness did not show lateralised results even with this induction method. This could be due to the fact that they rely mainly on movements of the upper part of the face, which are innervated bilaterally (see Figure 2.1).

EMOTIONAL VS. MOTOR CONTAGION

The next step in my work was to study how the two induction methods could differently affect emotional expressions. I then performed a comparison analysis between the two Experiments for each emotional expression. In particular, I investigated the different contribution of the two methods in eliciting posed and spontaneous expressions and in influencing the parts of the face distributed along the horizontal (lower vs. upper) and vertical (left vs. right) axis.

Posed vs. Spontaneous and Experiment 1 vs. 2

In the lower part of the face, spatial and speed parameters revealed significant main effects of the Experiment and interactions between Experiment and Condition for all expressions except sadness. In particular, posed expressions of happiness showed higher peak Velocity and Acceleration during Motor Contagion (Exp 2) than during Emotional Contagion (Exp 1). Spontaneous expressions of disgust showed higher peak Acceleration and Deceleration in Experiment 1 than Experiment 2. Expressions of fear showed higher peak Distance, Velocity, Acceleration, and Deceleration for posed expressions in Experiment 2 and for spontaneous expressions in Experiment 1.

In the upper part of the face, spatial parameters revealed a significant two-way interaction between Experiment and Condition for the expression of disgust: spontaneous expressions showed wider peak Distance during Experiment 1 than Experiment 2. The expression of anger also revealed two significant interactions between Experiment and Condition. During posed expressions, Deceleration peak was higher and Maximum Distance was reached later for Experiment 1 than Experiment 2.

Left vs. Right and Experiment 1 vs. 2

In the lower part of the face, no relevant contrast was found between Experiment 1 and Experiment 2.

In the upper part of the face, the analysis revealed a significant two-way interaction between Experiment and Side of the face for the expression of disgust: the Left Eyebrow was more distal in Experiment 1 than Experiment 2.

Overall, these results show that activating the Voluntary Pathway on command to perform a posed expression slightly influenced the lower and the upper part of the face, irrespective of the induction method.

SUMMARY

In general, adopting Motor Contagion as an induction method seems to activate all kinematic components of space, speed, and time to a greater degree than Emotional Contagion.

Specifically, Motor Contagion is particularly effective in inducing posed expressions of happiness, disgust, anger, and fear, as well as spontaneous expressions of surprise. While Emotional Contagion is better at triggering spontaneous reactions of disgust and fear. Sadness, on the other hand, seem to be elicited equally by both methods.

IRI Questionnaire

HAPPINESS

Correlation analyses on happy expressions showed different degrees of effectiveness of the two methods of induction (Emotional vs Motor Contagion) in the lower part of the face depending on the type of people being induced. In particular, the adoption of video clips extracted from comedies (Exp1) activated greater and quicker spontaneous smiles in people who tend to step into the shoes of fictional characters (Fantasy subscale) and in those who show feelings of sympathy and concern (Empathic Concern subscale). The amplitude of posed smiles was also positively correlated with these subscales, as well as with Perspective Taking.

When Motor Contagion was induced (Exp 2), instead, the adoption of video clips showing smiling people activated a delayed smile in participants who had higher feelings of personal anxiety and unease in tense interpersonal settings (Personal Distress subscale). Said otherwise, who tend to be moved by people expressing their emotional distress resonate better while watching direct examples of emotional expression.

SURPRISE

Correlation analyses on surprised expressions showed different degrees of effectiveness of the two methods of induction (Emotional vs Motor Contagion) in the lower part of the face depending on the type of people being induced. In particular, the adoption of video clips extracted from films (Exp 1) activated smaller and delayed posed expressions and anticipated spontaneous expressions in people with high scores on the Cognitive scale.

When Motor Contagion was induced, instead, the adoption of videos showing surprised people (Exp 2) induced a delayed peak in the spontaneous expression of surprise in people who tend to resonate with other’s emotional states (Emotional Scale). Said otherwise, participants who tend to be moved by people expressing their surprise will resonate better while watching direct examples of surprised expressions.

DISGUST

No significant correlation emerged in either the lower or upper part of the face.

ANGER

Correlation analyses on angry expressions showed different degrees of effectiveness of the two methods of induction (Emotional vs Motor Contagion) in both the lower and upper parts of the face depending on the type of people being induced. Interestingly, in Experiment 1 one of the 3 stimuli was not a movie scene, but an extremely difficult video game that triggered anger in the participant. These stimuli activated wider and quicker posed movements of the mouth and eyebrows in people who have greater feelings of personal anxiety and unease in tense interpersonal settings (Personal Distress subscale). Spontaneous expressions of anger, instead, were anticipated on the mouth of people who tend to spontaneously adopt the psychological point of view of others (Perspective Taking subscale).

When Motor Contagion was induced, the adoption of video clips showing people in the flow of anger (Exp 2) induced a smaller Deceleration in the Eyebrows of people with higher feelings of personal anxiety and unease in tense interpersonal settings (Personal Distress subscale).

SADNESS

Correlation analyses on sad expressions for Experiment 1 showed significant correlations in all the subscales except the Perspective Taking. However, these results are unreliable due to the limited number of participants (N=3) who completed the task.

When Motor Contagion was induced (Exp 2), the adoption of video clips showing sad people activated smaller and slower posed movements of the mouth and eyebrows in people with higher scores on the Cognitive scale. Whereas wider and quicker posed movements of the mouth were observed in people with higher scores on the Emotional scale. On the other hand, spontaneous expressions of sadness were characterised by a smaller eyebrow Deceleration in people who show “other-oriented" feelings of sympathy and concern (Empathic Concern subscale).

FEAR

Correlation analyses on expressions of fear showed different degrees of effectiveness of the two methods of induction (Emotional vs Motor Contagion) in the lower part of the face depending on the type of people being induced. In particular, the adoption of video clips extracted from films (Exp 1) activated smaller and quicker posed expressions in people with high scores on the Emotional scale. When Motor Contagion was induced, instead, the adoption of videos that showed people caught in the midst of fear (Exp 2) activated an accelerated peak in the posed expressions of fear in people who tend to who spontaneously adopt the psychological point of view of others (Perspective Taking subscale, Cognitive scale).

SUMMARY

Overall, I observed 22 strong and very strong correlations with the Emotional scale (11 for EC subscale and 11 for PD) and only 10 with the Cognitive scale (5 for PT subscale and 5 for FS). In kinematic terms, the parameters that correlate the most are those of speed.

Mixed Emotions

Multiple emotions are very frequent in every-day life. The Results from my new CER paradigm show that current validation studies (Sowden et al., 2021), such as those used in Experiments 1 and 2, might not be sensitive enough to bring out different emotional nuances. In particular, anger and fear ratings showed a secondary component of disgust and surprise, respectively. This means that kinematic analysis in Experiments 1 and 2 might have been influenced by both principal and secondary emotional components. In fact, expressions of anger and disgust shared a number of kinematic components moving in the same direction: Distance and peak Velocity were higher during posed than during spontaneous expressions for both angry and disgusted expressions. The same characteristics also emerged for expressions of fear and surprise: Distance and peak Velocity were higher during posed than spontaneous expressions for both these emotions. This finding suggests that future studies should carefully consider using the CER paradigm and/or other measures of mixed emotions before investigating the expression of emotion.

It is generally accepted that surprise co-determines the quality of several emotions such as disappointment and intensifies other emotions such as joy and sadness (Mellers et al., 1997). Here, we strikingly demonstrated its widespread presence in other expressions of basic emotions.

CONCLUSIONS

EMOTIONAL AND MOTOR CONTAGION

Emotional Contagion is the process whereby one person "catches" emotions from other individuals (Hatfield et al., 1993). Studies on emotional contagion have shown that after being exposed to the facial expressions of "transmitters," observers demonstrate an affective response that corresponds to the emotions displayed by the former (Hess & Blairy, 2001). Motor mimicry involves unintentional imitation of the emotional expressions of interactants, which represents the first step of the contagion mechanism (Neumann & Strack, 2000). Furthermore, Deng and Hu (2018) identified social contagion should be considered as equally or more important than facial contagion. Crucially, Emotional Contagion does not only occur when observing other faces. Audio and video contents, such as music, films, cartoons, commercials, are effective tools for communicating emotions (see Herrando & Constantinides, 2021; Isabella & Carvalho, 2016). In this dissertation thesis, I adopted the term Emotional Contagion to indicate an induction method that used emotional scenes, and the term Motor Contagion to indicate the effect obtained when observing other dynamic faces.

Embodiment theories (e.g., Barsalou et al., 2003; Niedenthal, 2007) propose that individuals process emotion-related information by reactivating neural states involved in their own prior perceptual, expressive, and affective experiences. As reported by Rouby et al. (2016): "these theories suggest that perceiving and thinking about emotion involve perceptual, somato-visceral, and *motor* re-experiencing of the relevant emotion in the self" (p. 76). Thus, individuals process emotion-related information by reactivating neural states involved in their own prior perceptual and affective experiences (Niedenthal, 2007). Consistent with this, recent research has shown that both hearing and reproducing vocalizations of emotions results in congruent self-reported emotions and specific facial behaviors. Research also showed that motor execution, observation, and imagery of movements when expressing an emotion can also enhance the corresponding affective state (R. Shafir et al., 2015; T. Shafir et al., 2013). In other words, motor execution and imagery, as well as the observation of whole-body dynamic expressions, increase the corresponding subjective feeling in the observer (T. Shafir et al., 2013). Theories of emotional embodiment interpret such responses as simulations of others' nonverbal expressions and affective states, which provide a basis for understanding and facilitate the interpersonal transfer of emotion (Barsalou et al., 2003; Niedenthal, 2007).

A non-trivial question concerns whether the Motor Contagion occur only in terms of strict imitations of an observed behavior, or it is a multi-modal phenomenon. Indeed, the cross-channel simulation theory suggests that matching another's emotion displays might occur across different expressive channels, such as smiling upon hearing laughter (e.g., Hawk et al., 2012; Provine, 1992, 1996). When individuals experience a combination of emotional expressions with sufficient frequency, such as smiling and laughing, later introspection about a stimulus (e.g., another's laughter) can activate dynamic simulations of associated behaviors. This pattern completion "fills in" unperceived elements of the original experience (Barsalou et al., 2003) and may manifest as overt motor behavior (e.g., smiling). These simulations facilitate cognitive, emotional, and behavioral engagement with related stimuli.

Future studies adopting different perceptual modalities will unveil the basic mechanisms underlying Motor Contagion.

COVID-19 PANDEMIC

Investigating the relative contributes of upper and lower facial cues to emotion expression is particularly interesting in the light of the recent Covid-19 pandemic. Medical facemasks occluding the lower portion of the face were a pervasive feature in everyday lives. These masks are clearly designed for preventing infection. However, they had a tremendous impact on emotion recognition. In particular, results from a just-published study (Marini et al., 2021) showed that mask-wearing had two problematic side-effects. First, by making the mouth invisible, they interfered with the recognition of emotional states. Moreover, they compromised facial mimicry reducing therefore emotional contagion (Dimberg et al., 2011; Hess & Fischer, 2013; Kastendieck et al., 2022; Palagi et al., 2020; Tramacere & Ferrari, 2016). With unprecedented changes in nonverbal communication brought about by the COVID-19 pandemic, this research marks a first contribution to our understanding of the crucial roles played by upper and lower face areas in facial mimicry.

FUTURE DIRECTIONS

This dissertation thesis has the potential to uncover relevant empirical findings, with far-reaching implications. In facial recognition research, scholars are developing automated softwares through artificial intelligence (AI) and computer vision that can recognize faces, discriminate gender and detect age on 3-D videos. Guo and colleagues (2016), for example, have developed a large-scale dataset based on milions of images suitable for improving facial recognition and contributing to the development of sophisticated image captions and new video analysis. At the same time, these studies encounter a crucial ethical dilemma that divides researchers. Indeed, large sets of face images are pivotal for training and testing face recognition algorithms. However, these large sets of face images have been collected, almost entirely, without people's consent. Recently, in the prestigious journal Nature, Van Noorden (2020) addressed and elegantly illustrated the ethical problem of indiscriminate collection of face recognition data, suggesting a more cautious approach and more laboratory-controlled datasets captured from different angles and in different lighting conditions.

In clinical settings, there is an urgent need to identify functionally-relevant biomarkers that can sensitively track disease progression. Decreases in facial mobility (hypomimia), for instance, are common consequences of neurological disorders such as Parkinson's Disease (PD). So far, traditional assessments of facial movement and its degree of dysfunction relied on qualitative scales (e.g., the House-Brackmann Scale, the most widely used facial nerve grading system; House & Brackmann, 1985), which have limited validity due to reduced inter-observer agreement (Linstrom, 2002). Recently, Jeganathan and colleagues (2022) developed a new technique to study the dynamic facial expressions of people with affective disorders such as melancholia. The Authors developed a tool that combines computer vision with systems modelling and extracts the sequential expression of spatiotemporal states – composites of distinct facial actions, each expressed with a unique spectral fingerprint (Jeganathan et al., 2022). However, the absence of an accurate and universally accepted grading system - as the Clepsydra Model I adopted here – for assessing the severity of emotional impairment across studies makes comparisons of results invalid.

By introducing the concept of "individual emotion-decoding performance", it might be possible, in the future, also to provide a reference to compare performance between typically and atypically developing children (e.g., children affected by Autism Spectrum Disorder, who show difficulties in reading emotions; Wieckowski & White, 2017), to early detect conditions characterized by the same deficit (e.g., Alexitimia and Huntington's disease), but also, crucially, to assess the positive effects of rehabilitative interventions.

In applicative terms, these findings may also inform future research on brain–computer interfaces (Namba et al., 2018) which seek to 'read' the emotional experiences of users and predict their behavior. Modeling the situated nature of emotions may give technology greater purchase in these integration efforts. Moreover, providing a new taxonomy that can span a continuous spectrum of emotion expressions would pave the way for human-computer interaction research (Pantic & Bartlett, 2007; Sahaï et al., 2017). Increasing efforts are nowadays targeted towards developing robotic systems able to recognize and respond to emotional signals, which can be applied in fields as security, medicine, education and digital communication. Researchers from psychology and computer science should embrace a unique and rich taxonomy to increase knowledge transfer and dialogue.

Finally, in order to address the rich complexity of expressions performed during nuanced emotional experiences such as a mixed emotional state, a top-down assessment test like the CER task might be very useful. The basic idea of my CER task is to find a connection between the complexity of the world and the minimalist rigor of the laboratory to capture the multiple characteristics of an emotional state (physical, mental, and situational), as suggested by Hoemann and colleagues (2017). By combining the CER task with three-dimensional motion analysis techniques, it will then be possible to detect any correlations or discrepancies between the mixed self-report (e.g., fear and surprise) and the kinematic index of overlapped emotional expressions.

This could be an effective tool to assess whether our emotion expression system can produce mixed expressions before or even without awareness.

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APPENDICES

APPENDIX I: IRI

Troverai ora una lista di affermazioni che possono essere più o meno vere / false per te.
Non ci sono risposte giuste o sbagliate: basati sulle tue sensazioni ed opinioni.
Ti chiediamo di leggere attentamente ciascuna affermazione e di indicare la tua opinione con i numeri:

- **1** se essa è **Mai vera** per te
- **2** se essa è **Raramente vera** per te
- **3** se essa è **Qualche volta vera** per te
- **4** se essa è **Spesso vera** per te
- **5** se essa è **Sempre vera** per te

1 Mai vera per me	2 Raramente vera per me	3 Qualche volta vera per me	4 Spesso vera per me	5 Sempre vera per me

	Mai vera per me				Sempre vera per me
1. Sogno ad occhi aperti e fantastico, con una certa regolarità, sulle cose che potrebbero accadermi.	1	2	3	4	5
2. Provo spesso sentimenti di tenerezza e di preoccupazione per le persone meno fortunate di me.	1	2	3	4	5
3. A volte trovo difficile vedere le cose dal punto di vista di un'altra persona.	1	2	3	4	5
4. A volte non mi sento particolarmente dispiaciuto/a per le altre persone che hanno problemi.	1	2	3	4	5
5. Resto veramente coinvolto/a dagli stati d'animo dei protagonisti di un racconto.	1	2	3	4	5
6. In situazioni d'emergenza, mi sento apprensivo e a disagio.	1	2	3	4	5
7. Riesco solitamente ad essere obiettivo/a quando guardo un film o una rappresentazione teatrale e raramente mi lascio coinvolgere del tutto.	1	2	3	4	5
8. In caso di disaccordo, cerco di tenere conto del punto di vista di ognuno prima di prendere una decisione.	1	2	3	4	5
9. Quando vedo qualcuno che viene sfruttato, provo sentimenti di protezione nei suoi confronti.	1	2	3	4	5
10. A volte mi sento indifeso/a quando mi trovo in situazioni emotivamente coinvolgenti.	1	2	3	4	5
11. Qualche volta cerco di comprendere meglio i miei amici immaginando come appaiono le cose dalla loro prospettiva.	1	2	3	4	5

12. Mi accade raramente di essere coinvolto/a da un buon libro o da un bel film.	1	2	3	4	5
13. Quando vedo qualcuno farsi male tendo a rimanere calmo.	1	2	3	4	5
14. Le disgrazie degli altri solitamente non mi turbano molto.	1	2	3	4	5
15. Se sono sicuro di avere ragione su qualcosa, non perdo tempo ad ascoltare le ragioni degli altri.	1	2	3	4	5
16. Dopo aver visto una commedia o un film mi sento come se fossi stato uno dei protagonisti.	1	2	3	4	5
17. Mi spaventa il fatto di trovarmi in situazioni che provocano tensione emotiva.	1	2	3	4	5
18. Quando vedo qualcuno che viene trattato ingiustamente, talvolta mi capita di non provare molta pietà per lui.	1	2	3	4	5
19. Solitamente sono molto efficace nel far fronte alle situazioni d'emergenza.	1	2	3	4	5
20. Spesso mi sento abbastanza colpito dalle cose che vedo accadere.	1	2	3	4	5
21. Credo che ci siano due prospettive diverse per ogni questione e cerco di capirle entrambe.	1	2	3	4	5
22. Mi descriverei come una persona dal cuore piuttosto tenero.	1	2	3	4	5
23. Quando guardo un bel film riesco facilmente ad immedesimarmi nel personaggio principale.	1	2	3	4	5
24. Tendo a perdere il controllo durante le emergenze.	1	2	3	4	5
25. Quando sono in contrasto con qualcuno, solitamente provo a "mettermi nei suoi panni" per un po'.	1	2	3	4	5
26. Quando leggo una storia o un romanzo interessante, immagino come mi sentirei se gli avvenimenti della storia accadessero a me.	1	2	3	4	5
27. Quando vedo qualcuno che in una situazione di emergenza necessita disperatamente di aiuto, vado in crisi.	1	2	3	4	5
28. Prima di criticare qualcuno provo ad immaginare come mi sentirei se fossi al suo posto.	1	2	3	4	5

APPENDIX II

Table 1. Descriptive Statistics for the SAM and CER scores divided between female and male.

			Median	Mean	SE	SD	Min	Max
Happiness	SAM - valence	females	3.333	3.193	0.237	1.032	1.333	5.000
	SAM - valence	males	3.333	3.704	0.232	0.696	2.667	4.667
	SAM - arousal	females	7.000	6.772	0.256	1.117	4.000	8.333
	SAM - arousal	males	6.333	6.370	0.211	0.633	5.333	7.333
	CER - happiness	females	1.333	1.544	0.164	0.713	1.000	3.667
	CER - happiness	males	2.333	2.296	0.349	1.047	1.000	4.333
	CER - surprise	females	6.333	5.649	0.451	1.964	1.667	8.667
	CER - surprise	males	5.667	5.593	0.487	1.460	3.000	8.000
	CER - disgust	females	2.333	2.474	0.358	1.561	1.000	6.000
	CER - disgust	males	1.333	2.148	0.445	1.335	1.000	4.000
	CER - anger	females	1.667	2.263	0.368	1.605	1.000	6.333
	CER - anger	males	1.000	2.519	0.626	1.879	1.000	5.667
	CER - sadness	females	2.333	2.597	0.314	1.368	1.000	5.000
	CER - sadness	males	3.000	2.963	0.637	1.911	1.000	5.333
	CER - fear	females	6.333	6.000	0.498	2.169	1.000	8.667
	CER - fear	males	5.333	5.592	0.433	1.299	4.000	7.333
Surprise	SAM - valence	females	7.333	7.105	0.194	0.846	5.333	8.333
	SAM - valence	males	6.667	6.963	0.211	0.634	6.000	7.667
	SAM - arousal	females	5.000	4.842	0.333	1.450	2.000	7.667
	SAM - arousal	males	5.000	4.889	0.404	1.213	3.000	7.000
	CER - happiness	females	7.000	6.825	0.285	1.244	3.333	8.667
	CER - happiness	males	6.667	6.815	0.216	0.648	6.000	8.000
	CER - surprise	females	4.333	4.474	0.505	2.201	1.000	8.000
	CER - surprise	males	3.333	4.222	0.550	1.650	2.333	6.333
	CER - disgust	females	1.000	1.175	0.100	0.436	1.000	2.333
	CER - disgust	males	1.000	1.148	0.148	0.444	1.000	2.333
	CER - anger	females	1.000	1.210	0.115	0.499	1.000	2.333
	CER - anger	males	1.000	1.185	0.148	0.444	1.000	2.333
	CER - sadness	females	1.333	1.719	0.238	1.038	1.000	4.333
	CER - sadness	males	1.000	1.593	0.277	0.830	1.000	3.333
	CER - fear	females	1.000	1.351	0.129	0.561	1.000	2.667

	CER - fear	males	1.000	1.111	0.079	0.236	1.000	1.667
Disgust	SAM - valence	females	3.667	3.807	0.220	0.958	2.333	5.667
	SAM - valence	males	4.667	5.111	0.373	1.118	4.000	7.000
	SAM - arousal	females	6.000	5.825	0.341	1.488	2.667	8.333
	SAM - arousal	males	5.000	5.222	0.385	1.155	3.667	7.000
	CER - happiness	females	2.667	2.684	0.253	1.103	1.000	4.667
	CER - happiness	males	4.333	4.815	0.556	1.668	3.000	7.667
	CER - surprise	females	5.667	5.035	0.474	2.066	2.000	8.333
	CER - surprise	males	4.000	4.518	0.596	1.788	2.000	7.333
	CER - disgust	females	7.000	7.035	0.379	1.651	2.000	9.000
	CER - disgust	males	5.667	5.222	0.369	1.106	3.667	6.667
	CER - anger	females	2.333	2.737	0.405	1.766	1.000	6.000
	CER - anger	males	1.667	1.852	0.427	1.281	1.000	5.000
	CER - sadness	females	1.333	1.877	0.291	1.268	1.000	5.000
	CER - sadness	males	2.333	2.185	0.409	1.226	1.000	4.000
	CER - fear	females	1.333	2.193	0.321	1.398	1.000	5.000
	CER - fear	males	1.000	1.222	0.124	0.373	1.000	2.000
Anger	SAM - valence	females	3.000	3.228	0.216	0.943	1.333	5.000
	SAM - valence	males	4.333	4.481	0.356	1.069	3.333	6.333
	SAM - arousal	females	5.333	5.631	0.201	0.874	4.000	7.333
	SAM - arousal	males	4.667	4.593	0.447	1.341	3.000	6.333
	CER - happiness	females	1.667	1.982	0.282	1.230	1.000	5.000
	CER - happiness	males	2.667	3.148	0.506	1.519	1.667	5.667
	CER - surprise	females	2.333	3.298	0.443	1.931	1.000	7.000
	CER - surprise	males	2.667	2.926	0.571	1.714	1.000	6.000
	CER - disgust	females	5.000	5.000	0.502	2.189	1.000	8.333
	CER - disgust	males	3.667	4.296	0.679	2.037	1.000	8.000
	CER - anger	females	6.000	5.351	0.334	1.455	2.667	7.667
	CER - anger	males	5.000	4.518	0.643	1.930	1.333	7.333
	CER - sadness	females	3.000	3.474	0.430	1.874	1.000	7.333
	CER - sadness	males	3.333	2.963	0.410	1.230	1.000	4.667
	CER - fear	females	1.333	2.053	0.324	1.411	1.000	6.000
	CER - fear	males	1.333	2.074	0.512	1.535	1.000	5.000
Sadness	SAM - valence	females	2.667	2.667	0.192	0.839	1.333	4.333
	SAM - valence	males	2.667	3.000	0.249	0.746	2.000	4.000
	SAM - arousal	females	5.667	5.491	0.287	1.249	3.000	8.000

	SAM - arousal	males	5.333	5.407	0.282	0.846	4.333	7.000
	CER - happiness	females	1.000	1.281	0.115	0.500	1.000	2.333
	CER - happiness	males	1.000	1.407	0.182	0.547	1.000	2.333
	CER - surprise	females	2.667	2.912	0.315	1.374	1.000	6.667
	CER - surprise	males	3.333	3.296	0.578	1.735	1.000	6.333
	CER - disgust	females	1.667	1.965	0.299	1.305	1.000	6.000
	CER - disgust	males	2.333	2.815	0.614	1.842	1.000	5.667
	CER - anger	females	3.667	3.789	0.462	2.013	1.000	7.333
	CER - anger	males	4.333	3.444	0.624	1.871	1.000	5.333
	CER - sadness	females	7.333	7.105	0.297	1.296	2.667	9.000
	CER - sadness	males	6.667	6.593	0.444	1.331	4.000	8.000
	CER - fear	females	1.667	2.825	0.412	1.796	1.000	6.667
	CER - fear	males	1.667	3.259	0.765	2.296	1.000	6.667
Fear	SAM - valence	females	3.333	3.193	0.237	1.032	1.333	5.000
	SAM - valence	males	3.333	3.704	0.232	0.696	2.667	4.667
	SAM - arousal	females	7.000	6.772	0.256	1.117	4.000	8.333
	SAM - arousal	males	6.333	6.370	0.211	0.633	5.333	7.333
	CER - happiness	females	1.333	1.544	0.164	0.713	1.000	3.667
	CER - happiness	males	2.333	2.296	0.349	1.047	1.000	4.333
	CER - surprise	females	6.333	5.649	0.451	1.964	1.667	8.667
	CER - surprise	males	5.667	5.593	0.487	1.460	3.000	8.000
	CER - disgust	females	2.333	2.474	0.358	1.561	1.000	6.000
	CER - disgust	males	1.333	2.148	0.445	1.335	1.000	4.000
	CER - anger	females	1.667	2.263	0.368	1.605	1.000	6.333
	CER - anger	males	1.000	2.519	0.626	1.879	1.000	5.667
	CER - sadness	females	2.333	2.597	0.314	1.368	1.000	5.000
	CER - sadness	males	3.000	2.963	0.637	1.911	1.000	5.333
	CER - fear	females	6.333	6.000	0.498	2.169	1.000	8.667
	CER - fear	males	5.333	5.592	0.433	1.299	4.000	7.333

Table 2. T.test for paired samples of the ERC scores divided by video clip. (Ps>0.05 are indicated in bold)

Happiness video clips	t	p
happiness - surprise	10.671	< 0.001
happiness - disgust	16.149	< 0.001
happiness - anger	14.714	< 0.001
happiness - sadness	19.016	< 0.001
happiness - fear	25.598	< 0.001

Anger video clips	t	p
anger - happiness	7.898	< 0.001
anger - surprise	7.176	< 0.001
anger - disgust	**1.579**	**0.118**
anger - sadness	6.755	< 0.001
anger - fear	10.927	< 0.001

Surprise video clips	t	p
surprise - happiness	-8.58	< 0.001
surprise - disgust	10.726	< 0.001
surprise - anger	10.743	< 0.001
surprise - sadness	8.007	< 0.001
surprise - fear	11.199	< 0.001

Sadness video clips	t	p
sadness - happiness	27.279	< 0.001
sadness - surprise	15.248	< 0.001
sadness - disgust	20.101	< 0.001
sadness - anger	13.101	< 0.001
sadness - fear	15.652	< 0.001

Disgust video clips	t	p
disgust - happiness	6.147	< 0.001
disgust - surprise	4.539	< 0.001
disgust - anger	13.479	< 0.001
disgust - sadness	14.26	< 0.001
disgust - fear	16.509	< 0.001

Fear video clips	t	p
fear - happiness	11.202	< .001
fear - surprise	**0.847**	**0.400**
fear - disgust	10.721	< 0.001
fear - anger	10.666	< 0.001
fear - sadness	9.743	< 0.001

Publications and presentations

Full peer review journal articles

Sartori, L., Spoto, A., Gatti, M., & **Straulino, E.** (2020). The Shape of Water: How Tai Chi and Mental Imagery Effect the Kinematics of a Reach-to-Grasp Movement. Frontiers in Physiology, 11, 297. doi: 10.3389/fphys.2020.00297

Straulino, E., Scarpazza, C., & Sartori, L. (under review). What is missing in the study of emotion expression?

Straulino, E., Scarpazza, C., Miolla, A., Spoto, A., & Sartori, L. (under review). Motor and Emotional Contagion: posed and spontaneous happiness through the kinematic lens.

Straulino, E., Scarpazza, C., Spoto, A., Chozas Barrientos, B., & Sartori, L. (submitted). The left side of a posed smile.

International and national academic conference presentations

Straulino, E., Miolla, A, Scarpazza, C., & Sartori, L. (2022) Facial kinematics of spontaneous and posed expression of emotions. *International Society for Research on Emotion (ISRE)*, Los Angeles, California USA. July 15 – 18. Poster. Early Career Researcher Section (ECRS) Poster Award: Second Runner-Up.

Straulino, E., Chozas Barrientos, B., Betti, S., Scarpazza, C., & Sartori, L. (2022) Lateralized happiness kinematics of Left and right face. *Società Italiana di Psicofisiologia e Neuroscienze Cognitive (SIPF)*, Udine, Italy. September 15 – 17. Poster.

Straulino, E., Miolla, A, Scarpazza, C., & Sartori, L. (2021) Facial kinematics of genuine and simulated fear. *Società Italiana di Psicofisiologia e Neuroscienze Cognitive (SIPF)*, Palermo, Italy. September 30 – October 2. Poster.

Straulino, E., Miolla, A, Scarpazza, C., & Sartori, L. (2021) Expression of emotions: kinematic characterization of genuine and posed facial expressions. *XXVII CONGRESSO NAZIONALE Associazione Italiana di Psicologia Sezione Sperimentale*, Lecce, Italy. September 8 – 10. Abstract MT19.3 - Conference Presentation.

Straulino, E., Miolla, A, Scarpazza, C., & Sartori, L. (2021) Facial kinematic characterization of genuine and simulated expressions. *5th International Conference of the European Society for Cognitive and Affective Neuroscience (ESCAN)*, Virtual Meeting. June 23-26. *Poster*.

Straulino, E., Miolla, A, Scarpazza, C., & Sartori, L. (2020) True emotions: Kinematic characterization of genuine and simulated facial expressions. *Società Italiana di Psicofisiologia e Neuroscienze Cognitive (SIPF)*, Virtual Meeting. November 20,21,27,28. Poster.