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EXAMINING THE IMPACT OF TRAIT ANXIETY ON THE RECOGNITION OF FACIAL EMOTIONAL EXPRESSIONS

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Examining the impact of trait anxiety on the recognition of facial emotional expressions

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LISTE DES ABBRÉVIATIONS

SCI: Spinal cord injury
LSF: Low spatial frequency
HSF: High spatial frequency
fMRI: Functional Magnetic Resonance Imaging
PET: Positron Emission Technology (PET)
pSTS: Posterior superior temporal sulcus

RESUMÉ

Question : Cette thèse comporte deux articles portant sur l'étude d'expressions faciales émotionnelles. Le processus de développement d'une nouvelle banque de stimuli émotionnels fait l'objet du premier article, alors que le deuxième article utilise cette banque pour étudier l'effet de l'anxiété de trait sur la reconnaissance des expressions statiques.

Méthodes : Un total de 1088 clips émotionnels (34 acteurs X 8 émotions X 4 exemplaire) ont été alignés spatialement et temporellement de sorte que les yeux et le nez de chaque acteur occupent le même endroit dans toutes les vidéos. Les vidéos sont toutes d'une durée de 500ms et contiennent l'Apex de l'expression. La banque d'expressions statiques fut créée à partir de la dernière image des clips. Les stimuli ont été soumis à un processus de validation rigoureux. Dans la deuxième étude, les expressions statiques sont utilisées conjointement avec la méthode Bubbles dans le but d'étudier la reconnaissance des émotions chez des participants anxieux.

Résultats : Dans la première étude, les meilleurs stimuli ont été sélectionnés [2 (statique & dynamique) X 8 (expressions) X 10 (acteurs)] et forment la banque d'expressions STOIC. Dans la deuxième étude, il est démontré que les individus présentant de l'anxiété de trait utilisent préférentiellement les basses fréquences spatiales de la région buccale du visage et ont une meilleure reconnaissance des expressions de peur.

Discussion : La banque d'expressions faciales STOIC comporte des caractéristiques uniques qui font qu'elle se démarque des autres. Elle peut être téléchargée gratuitement, elle contient des vidéos naturelles et tous les stimuli ont été alignés, ce qui fait d'elle un outil de choix pour la communauté scientifique et les cliniciens. Les stimuli statiques de STOIC furent utilisés pour franchir une première étape dans la recherche sur la perception des émotions chez des individus présentant de l'anxiété de trait. Nous croyons que l'utilisation des basses fréquences est à la base des meilleures performances de ces individus, et que l'utilisation de ce type d'information visuelle désambigüise les expressions de peur et de surprise. Nous pensons également que c'est la névrose (chevauchement entre l'anxiété et la dépression), et non l'anxiété même qui est associée à de meilleures performances en reconnaissance d'expressions faciales de la peur. L'utilisation d'instruments mesurant ce concept devrait être envisagée dans de futures études.

Mots-clés: Expressions faciales d'émotion, perception des émotions, méthode *Bubbles*, anxiété de trait, névrose

ABSTRACT

Question: This thesis describes a new database of facial emotional expressions; created specifically for eye-tracking and classification image experiments. This database serves as a basis for the second study, which explores the effect of trait anxiety on the perception of static facial emotional expressions.

Methods: Actors were recruited to express facial emotional expressions. Thousands of 1-second movie clips that contained the least head movement and appeared genuine were extracted from the raw videos and selected for the validation. A total of 1088 clips (34 actors X 8 expressions X 4 exemplar) were spatially aligned so that facial features across the stimuli occupied the same space. They were also temporally aligned so that all clips began on the last neutral frame and truncated on the 15th frame (500ms). The last frame (apex) of the clips was extracted to form the static database. Two groups of participants validated the dynamic (N35) and static (N35) stimuli. The static images were used in the 2nd study where participants (N27) varying in trait anxiety were asked to recognize emotional faces, partially revealed through Gaussian apertures (*Bubbles*).

Results: Study 1 describes the process by which the STOIC database was created. It showcases the 80 dynamic (and 80 static) emotional expressions (8 emotions X 10 actors) with the lowest entropy scores. Study 2 shows that trait anxiety is associated with performance and differential use of information. Anxious individuals use low spatial frequency (LSF) information from the mouth region and are better at recognizing negative emotions, especially fear and not anger.

Discussion: This thesis presents a new and freely downloadable emotion recognition database containing static and dynamic stimuli. The database possesses unique characteristics that will make it useful to the scientific community and clinicians. We used the static images in the second study to establish a baseline and gain a better understanding about the use of information contained in faces to recognized emotional expressions. The next phase of the project will be to explore the effects of anxiety and depression on the perception of dynamic expressions. We speculate that the use of LSF information in our anxious group disambiguated fear from surprise and led to better performance for that emotion. In addition, we think the overlap between anxiety and depression, which was associated with better performances, may be attributed to concept of neuroticism.

Keywords: Facial emotional expressions, emotion perception, *Bubbles* method, trait anxiety, neuroticism, stoic database.

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1. INTRODUCTION

1.1. EMOTIONS: HISTORY AND CONCEPTUALIZATION

1.1.1. History of emotions. The ancient Greeks were some of the first to talk about emotions. Sayings such as, “you’re so stoic”, or “our relationship is purely platonic” are some of the legacies they left behind (For a more detailed discussion see Lyons, 1999). Contrary to Aristotle’s pragmatic view of human emotions, Plato had very little to say about them. He wished to control emotions with reason. Aristotle on the other hand, used emotions in politics. The Stoics later offered a more detailed account. As emotions were impulses to act, they did not condemn emotions; rather they took little account of emotions and looked suspiciously at emotional individuals. Hence the origin of the term being stoic: a dispassionate, stoical person. In short, they were more concerned about the cause of emotions, rather than a theory per se.

Descartes expanded on the concept of emotion. He believed animals could react under the stress of emotion, but could not experience them. In humans, he believed the pineal gland was the gateway to the soul and that perceptions would pass trough it to reach the soul. Once inside, the percept was compared to memory and a decision was made about the emotional significance of the stimulus. While the pineal gland is now believed to have very little to do with emotions, his views remained dominant for some time.

William James (1890) viewed emotions differently. He suggested that emotions arise from changes in physiology; that is, we are sad because we cry. His proposal was contested by Cannon (1927) who believed the brain was central to emotion. Cannon argued that if emotions and feelings arose from the periphery, spinal cord injuries (SCI) would prevent emotional reactions. Cannon also argued that if physiological arousal caused emotion, the injection of adrenaline, which directly influences autonomic function such as heart rate, would produce an emotional response. Marañón (1924) injected adrenaline to his subjects which caused emotional reactions in only 29% of them, despite measurable increases in heart rate and respiration. Cannon concluded that peripheral activity lacked specificity. This question was recently revisited by a group of researchers who found no differences in heart rate, emotional experience and the ratings of valence and arousal between control participants and those with SCI (Cobos, Sanchez, Garcia, Nieves Vera, & Vila, 2002). Interestingly, however, peripheral activity have been shown by others to be associated with different emotions (Ekman, Levenson, & Friesen, 1983). The Somatic Marker Hypothesis adds further complexity to the debate by suggesting that emotional signals arising from the body biases decision making and are integrated in the ventromedial prefrontal cortex (Bechara, Tranel, Damasio, & Damasio, 1996). While the conduit by which these peripheral signals reach the brain continues to be elucidated, recent preliminary findings in epilepsy patients implanted with vagus nerve stimulator show that vagus nerve stimulation improves performances on the Iowa Gabling Task used to assess the somatic marker hypothesis (Martin, Denburg, Tranel, Granner, & Bechara, 2004) These findings peripheral activity may play an important role in emotions and that the body to brain connection may be dependent on means other than the spinal cord (blood stream, vagus nerve).

The environment also plays a role in how we interpret physiological arousal (Cantril, 1934). Schachter's (1964) two-factor theory of emotion states that emotional reactions arise from both the environment (e.g., others' behaviour and arousal) and attribution (a cognitive component). He postulated the following scenarios; 1*) if a person is physiologically aroused but attributes his feelings to an external cause such as adrenaline, he will not associate the arousal with an emotion; 2) if an emotional competent stimulus is coupled with arousal, however, the person will attribute his feelings to that stimulus; 3) if a person finds himself in a situation that would typically give rise to an emotion, but feels no arousal, he will not experience an emotion.* He tested this experimentally by injecting participants with either adrenaline or a saline solution. Participants were informed about the true side effects, told about false side effect or simply told nothing, and all participants were either subjected to a euphoric or an anger condition. Results indicated that in the euphoria condition the misinformed participants felt the happiest, followed by the ignorant group. Those that were told of the true side effects felt the least happy as they attributed their arousal to the adrenaline. In the anger condition, the ignorant felt most anger. While the theory has received considerable attention the study still needs to be replicated.

A final important cognitive variable is appraisal (Arnold, 1969). Appraisal refers to a cognitive process in which a stimulus is evaluated as either emotionally relevant or not. To illustrate its importance Lazarus and Alfert (1964) asked participants to view short emotional clips. They manipulated the context in which the clips were presented (e.g., while viewing a violent mortal accident, participants were either told the people in the video were actors or real people). Those who were informed that actors were in the movies reacted less intensely than those who believed they were real people.

1.1.2. Basic emotions and feelings. The Miriam-Webster dictionary defines an emotion as, “the effective aspect of consciousness, a state of feeling, a conscious mental reaction (e.g. anger or fear) subjectively experienced as a strong feeling usually directed toward a specific object and accompanied by physiological and behavioural changes in the body”. Damasio (2003a) provides a more detailed description. He views emotions as reactions, which are visible to others through body posture, facial expressions, and prosody. They are collections of chemical and neural responses that form distinctive patterns and result in a temporary change in body states. They are pre-programmed actions that result in behaviour that are conducive to survival. Damasio argues they precede feelings because they came first during evolution. Emotions emerged by building upon simpler bodily reactions.

There is presently no agreed upon criteria on what constitutes a basic emotion, but most would agree that fear, anger, sadness, happiness, surprise, and disgust are basic emotions (Ekman, Sorenson, & Friesen, 1969; Plutchik, 1965). Some researchers believe that pain and pleasure basic building blocks for emotion (Mowrer, 1960). Panksepp (1982) suggested that expectancy, fear, rage and panic were basic emotions, while Watson (1930) proposed fear, love and rage were basic ones. Many other researchers have included different emotions, interestingly; the most consistent thing that have arisen from this topic is the general lack of agreement between researchers (Ortony & Turner, 1990). Two main approaches seem to form the basis of the disagreement. The first is biological and the other is psychological. The biological perspective, as the name suggests, examines the biological basis of emotion and functional significance of each emotion to the species. The psychological perspective often begins with the assumption that basic emotions, like primary colors, can be combined to create non-basic emotions and that the number of emotions is in a sense, limitless (Ortony & Turner, 1990)

Though the debate is far from over, Paul Ekman suggested that there are at least six basic emotions (fear, anger, disgust, sadness, surprise and happiness) because they are expressed and recognized similarly across cultures. He showed photographs of emotional faces to an aboriginal tribe in New Guinea with very little exposure to the western world (hence they did not have the opportunity to learn these emotions) (Ekman, et al., 1969). Those tested managed to recognize the expressions relatively accurately. He also took photographs of aboriginal expressing emotions and showed them to people in America and found they were also well recognized. In addition, this set of emotions are induced by similar situations, have a predictable physiology such as heart rate, blood pressure, skin conductance, tightening of muscles and are expressed in a distinct and unique way (Ekman, 2009; Schyns, Petro, & Smith, 2009; Waller, Cray, & Burrows, 2008).

While it may argued that surprise lacks an affective component and that it may not necessarily be an actual emotion (Ortony & Turner, 1990), it was added in the STOIC database that we created, as the expression is widely studied and its inclusion in our database (see study 1 below), strengthens its utility. Neutral expressions were also added for research purposes as a control expression. Finally, pain expressions, which will be discussed more thoroughly later, were also added in the STOIC database for scientific curiosity and its clinical utility (e.g. patient pain behaviour).

1.1.3. Emotions and the brain. The field of affective neurosciences has seen tremendous growth since the introduction of neuroimaging technologies including functional Magnetic Resonance Imaging (fMRI) and Positron Emission Technology (PET) in the 1990s. Prior to this, lesion and electrical stimulation studies informed us about brain function. For example, Cannon (1927) and Bard (1928) noticed that the removal of the cerebral cortex of cats resulted in increased aggression, and that the removal of the hypothalamus tamed these same animals. Hess and Brugger (1943) provided support for this when they found that the electric stimulation of the posterior hypothalamus increased aggression. Based on these studies, Papez (1937) proposed that the emotional circuit of the brain included the hypothalamus, the hippocampus, the cingulate gyrus, the anterior region of the thalamus and the neo cortex for the experience of emotion. At approximately the same period, Kluver and Bucy (1937) found that the removal of the bilateral temporal lobes eliminated monkeys' tendency for fear and aggressive behaviour thus providing support for Papez's hypothesis. Later McLean (1949) proposed his triune brain hypothesis, in which he divided the human brain into three evolutionary and functionally distinct areas. The neocortex is responsible for reasoning and other higher faculties, the limbic system (paleopallium) for emotions and the reptilian brain (archipallium) for more basic "survival" mechanisms.

Decades later the role of the hemispheres in emotion was explored and two hypotheses were proposed. *The Right Hemisphere Hypothesis* suggests that the right hemisphere processes emotions regardless of valence. Patients with right hemisphere damage are more impaired in the perception of emotional faces (Adolphs, Jansari, & Tranel, 2001; Borod et al., 1998) and vocal intonations (Tucker, Watson, & Heilman, 1977) than individuals with left damage. In addition, the left part of the face expresses greater emotion than the right (Indersmitten & Gur, 2003; Nicholls, Wolfgang, Clode, & Lindell, 2002; Sackeim, Gur, & Saucy, 1978; Zhou & Hu, 2006) which is thought to be regulated by the right hemisphere. This could explain why artists have the tendency to expose left cheeks for aesthetics (Powell & Schirillo, 2009).

The Valence-Specific Hypothesis on the other hand asserts that the left hemisphere processes positive emotions, while the right hemisphere processes negative emotions (Killgore & Yurgelun-Todd, 2007). Unilateral brain damaged the left hemisphere has been shown to impair the perception of positive emotions, while damage to the right has been shown to impair the perception of a negative emotion (Borod, Koff, Perlman Lorch, & Nicholas, 1986; Jaeger, Borod, & Peselow, 1986). Both hypotheses have received support.

Deep within the hemispheres, the amygdala has been linked to fear recognition (Adolphs, Tranel, Damasio, & Damasio, 1994) experience (Tranel, Gullickson, Koch, & Adolphs, 2006) and expression (LeDoux, 2007). The amygdala also responds to anger, sadness, (Adolphs et al., 2005; Adolphs & Tranel, 2004; Carter & Pelphrey, 2008), and happiness expressions (Juruena et al., 2010; Sato, Kochiyama, Uono, & Yoshikawa, 2010). This has led some to believe the structures are “relevance” or “saliency” detectors (Hindi Attar, Muller, Andersen, Buchel, & Rose, 2010; Kennedy & Adolphs, 2010; Ousdal et al., 2008; Sander, Grafman, & Zalla, 2003; Zaretsky, Mendelsohn, Mintz, & Hendler, 2010), but it’s true role in emotion perception continues to be elucidated (Adolphs, 2010). In fact damage to other regions of the brain can impair fear perception despite intact amygdalae (Roy, Gosselin, Gosselin, & Peretz, 2009).

Another structure that has received considerable attention is the insula. Though less is known about the insula, it has been linked to the experience and perception of disgust (Calder, Keane, Manes, Antoun, & Young, 2000; Ibanez, Gleichgerrcht, & Manes, 2010). This has largely been validated by a meta-analytic study looking at brain imaging data (Vytal & Hamann, 2010). The study provides support for the modularity of other basic emotions as well, though less consistently. The fusiform Gyrus is also activated by the perception of facial expressions; however, the structure is believed to be associated with the face perception per se (Jemel, Coutya, Langer, & Roy, 2009).

1.2 FACIAL EXPRESSIONS OF EMOTION

1.2.1. Emotional expressions as signals. Facial emotional expressions provide a wealth of information about an individual's emotional state (Damasio, 2003b; LeDoux, 2000). They can also communicate intent (e.g., dominance or affiliation), needs (sadness for comfort) and threat information (fear, anger, disgust). Emotional expressions can also be used to manipulate the feelings of others (Schultheiss, Pang, Torges, Wirth, & Treynor, 2005). As most of us learn as children, it is possible to simulate an emotional state to get attention, receive sympathy and even induce guilt or aggression. Conversely, someone may attempt to conceal emotions (Ekman, O'Sullivan, & Frank, 1999).

What useful information is contained in facial expressions? From a computational viewpoint, expressions can be conceptualized as signals between a transmitter (face) and a decoder (human brain). These signals stem from facial features (eyes, mouth and the nose), their configuration and movements. Ekman and Friesen (1975) developed the Facial Action Coding System (FACS) to characterize this information.

> *“**Happiness** is communicated by drawing back and pulling up the corners of the mouth. The mouth may or may not be opened or showing teeth and wrinkles run from the nose to the corners of the mouth and wrinkles may also be apparent below the eyelids. In **surprise**, the brows are usually raised high and curved which results in the skin under the brow to be stretched. Horizontal wrinkles are apparent across the forehead, the eyelids are opened, and the jaw is dropped. In **fear**, the upper eyelids are raised, the lower ones are tensed and the sclera is exposed. The brows are raised and pulled together and wrinkles are apparent in the middle region of the forehead. The lips are slightly tensed and drawn back. For **disgust**, the nose is wrinkled, cheeks raised, the upper lip raised. The lower lip is also raised and pushed up and brow lowered. In **anger** the brows are drawn together and lowered, vertical lines are apparent between them and the lower and upper lid is tensed. Staring of the eyes, pressed lips, and the dilated nostrils may be apparent. In **sadness**, the inner corners of the eyebrows are drawn up; the skin under the eyebrow has a triangular shape with the inner corners being raised. The top of the eyelid is raised and the corners of the lips or down” (Ekman & Friesen, 1975).*

As will subsequently be discussed in greater detail, Schyns and his collaborators (2009), add that little similarity exist between the expression of basic emotions. Smith, Cottrell, Gosselin, & Schyns (2005) measured the facial characteristics associated basic emotions using a model observer and the *Bubbles* method (Gosselin & Schyns, 2001) and concluded that the human face and brain co-evolved to express and decode expressions.

1.2.2. The perception of emotional expressions. On the receiving end, Lundqvist, Esteves, & Ohman (2004) demonstrated, using schematic stimuli, that the brows, the eyes and the mouth facilitate the recognition of emotions. The brows and the mouth provided threat information; adding the eyes allowed participants to accurately recognize all emotions. Gouta and Miyamoto (2000) added that the top half of the face yields better recognition of *Anger*, *Fear*, *Surprise* and *Sadness*, while the bottom half of the face yields better recognition of *Disgust* and *Joy*.

The *Bubbles* method (Gosselin & Schyns, 2001) was used in two recent studies to identify peoples' use of information during an emotion recognition task (Roy et al., 2008; Smith, et al., 2005). In each trial all participants saw faces that were decomposed in five spatial frequency bands and presented through randomly positioned Gaussian apertures. Independent diagnostic filtering functions (one for each expression) were derived using the pixels significantly correlated with accuracy. Results indicated that the mouth region in low spatial frequencies was used to recognize surprise and happy expressions. The eyes in high spatial frequencies were used for fear, and in low spatial frequencies they were used for anger. The nose in low spatial frequencies was used for disgust, while the forehead in both low and high spatial frequencies was used for sadness.

1.2.3. The contributions of movement. Most studies that have looked at facial emotional expressions have used static stimuli, such as the ones developed by Ekman and Friesen (1975). These stimuli are potentially problematic because they neglect the dynamic nature of real life non-verbal communication and are usually unnaturally intense expressions. In addition, they are commonly presented for several seconds when in reality expressions such smiles are, in most instances, relatively shorter.

The uses of static expressions have in the past been much easier to study. Until very recently, photographs have been easier to manipulate and constituted simpler phenomena. Static stimuli have led to important discoveries (e.g., the role of different brain structures involved in emotion recognition, a better understanding of the social deficits in developmental disorders such as autism, the universality of basic emotion, etc.). Considering the current state of science and the technological advancements made in recent years allowing scientists to present videos and record behaviours on computers, the time is ripe to study dynamic facial emotional expressions.

There is no doubt that dynamic stimuli are more natural and more closely approximate real life social phenomena. From an experiential point of view, however, is there a difference between static and dynamic expressions? That is, does the human brain process them differently? Are dynamic expressions easier to recognize? Do they lead to different response styles or pattern? A handful of studies have begun to answer this question.

Bassili (1978) was one of the first to demonstrate that facial movement alone can provide sufficient emotional information to permit the recognition of certain emotions. He studied people's ability to recognize facial expressions using point-light displays (i.e. Johansson, 1973). In this procedure, randomly positioned white spots are placed on an actor's face, while the rest of the face is invisible. The actor was then asked to produce emotional expressions. In the dynamic condition, participants viewed the unfolding of the expression (moving dots), while in the static condition they saw the final configuration. Participants, who saw movement as opposed to no movement, were better at recognizing basic emotions, but they were not as good as when faces were completely visible.

More recently, some authors have begun suggesting that dynamic stimuli improve recognition accuracy particularly when expressions are subtle in nature or not intense (Ambadar, Schooler, & Cohn, 2005). Several groups have failed to find a difference between static and dynamic stimuli (Kamachi et al., 2001; LaBar, Crupain, Voyvodic, & McCarthy, 2003) and this could possibly be attributed to the stimuli they used. Although, the research in this area is still in its infancy, the next section will discuss a handful of papers that have begun to tackle the issue.

Harwood, Hall, and Shinkfield (1999) compared individuals with mental retardation to control participants on their ability to recognize static and dynamic facial emotional expressions from real movies. They found that participants were slightly better at recognizing dynamic expressions of sadness and anger, but not happiness, surprise, fear and disgust. In line with these finding, Wehrle et al. (2000) compared participants' ability to recognize dynamic schematic drawings based on the configuration of muscle movements. They demonstrated that dynamic expressions of happiness, fear, anger and sadness were slightly better recognized than static displays.

Ambadar et al. (2005) also studied peoples' ability to recognize static and dynamic facial emotional expressions. They proposed that intense static expressions, often unrealistic, might cloud or minimize the relative contribution of movement during a recognition task (e.g., create a ceiling effect). They attempted to control for the intensity of their stimuli by truncating videos obtained from Kanade, Cohn, & Tian (2000) at the onset of the expressions. They created four separate conditions (static, multi-static, dynamic and first-last) by manipulating the stimuli. In the multi-static condition, a mask presented for 200ms followed each emotional frame (500ms) in order to remove the appearance of motion. In the first-last condition a neutral frame was immediately followed by an emotional expression. Results indicated that movement in the dynamic condition significantly improved recognition accuracy when compared to both static and multi-static conditions. However, both the dynamic and the first-last conditions yielded similar results suggesting that the perception of change is the driving force behind the improved accuracy.

In a very similar paradigm, Bould and Morris (2008) replicated the work of Ambadar et al., (2005) and tested the hypothesis that high intensity displays mask the contribution of movement. They compared both subtle and intense emotional expressions and found that intense stimuli indeed masked the contribution of movement. These findings were replicated with animated faces (Katsyri & Sams, 2008). However, a recent investigation into this question suggested that greater efficiency is achieved with static as opposed to dynamic stimuli (Hammal, Gosselin, & Fortin, 2009). Although the implications of these findings are unknown, it highlights the notion that static and dynamic expressions are processed differently.

Temporal characteristics such as velocity may also contribute to our recognition abilities (Bould, Morris, & Wink, 2008). Kamachi et al. (2001) found that happy and surprise expressions are better recognized at faster velocities, anger at a medium velocity, and sadness at slow velocity. Sato and Yoshikawa (2004) also investigated velocity by asking participants to rate the naturalness of each expression. Increasing velocity increased the authenticity of surprise but not sadness expressions, while reducing velocity had opposite effects. Finally, velocity has also been shown to cause representation momentum and increases the perceived intensity of stimuli (Yoshikawa & Sato, 2008). This could explain in part why movement can improve recognition.

To summarize, this section explored the contribution of movement in the recognition of facial emotional expressions. Facial expressions are dynamic in nature. That is, peoples' facial expressions change as a function of our emotional state and the environment in which we are. Despite this, the fact that motion is processed differently by the human brain and that motion, in the form of change or representational momentum, can improve emotion recognition, static expressions are still preferred in research experiments. Research in the area is still at an early stage in its development. There is a need for well-controlled and freely available emotional expressions to compare the cognitive and neurological processes involved in the processing of static and dynamic expressions. The next section discusses the brain research comparing the processing of static and dynamic facial emotional expressions. The differences that will be presented highlight the fact that, despite similar recognition patterns (hit rates) and some overlap in brain regions (e.g., the amygdale for fear), these two sets of stimuli are processed very differently (Haxby, Hoffman, & Gobbini, 2000; Kilts, Egan, Gideon, Ely, & Hoffman, 2003; LaBar, et al., 2003).

1.2.4. The brain processes static and dynamic expression differently. The human brain appears to process dynamic and static stimuli differently. Several studies report greater brain activation for the dynamic stimuli in various cortical and subcortical regions (Haxby, et al., 2000; Kilts, et al., 2003; LaBar, et al., 2003). Distinct patterns of activation are also apparent. The superior temporal sulcus (STS), for example, is involved in the perception of dynamic expressions (Haxby, et al., 2000; Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005).

Kilts, et al., (2003) contrasted both dynamic and static happy and anger expressions using Positron Emission Topography (PET). Dynamic anger expressions recruited mainly the right lateralized medial, superior, middle and inferior frontal cortex and the cerebellum, while happiness was associated with activation of the temporal cortex, middle, medial and superior frontal cortex and cuneus. In contrast, static expressions activated regions involved in mental imagery including motor, prefrontal and parietal cortical network. Dynamic fearful expressions show enhanced activity in the amygdala, inferior occipital gyri, middle temporal gyri, superior temporal gyri and fusiform gyri, relative to static expression (Adolphs, 1999; Noesselt, Driver, Heinze, & Dolan, 2005). And with the exception of the amygdala, the same pattern of activation is observed for happiness.

Neuropsychological research also provides support for the idea that static and dynamic expressions are processed differently. Humphreys et al. (1993), studied a patient who could not recognize static emotional expressions, but who performed normally on a dynamic emotion recognition task. He had bilateral occipital lobe damage that extended anteriorly to the temporal lobes. Adolphs et al. (2003) also discussed another case with a similar profile. This patient sustained bilateral lesions to the amygdala, hippocampi, perirhinal, basal forebrain, anterior insula and parahippocampal cortex. His middle superior temporal (MST) and occipital-parietal cortices were spared. Based on the findings and the localization of the lesions, the authors speculated that dynamic expressions recruit the MST, parietal and frontal regions.

Overall, brain research despite also being in its infancy has contributed substantially to our understanding of processes involved in both static and dynamic expressions. While new discoveries will likely be made in the field, the current state of the literature does suggest that static and dynamic expressions are processed differently in the brain.

1.2.5. Emotion research in psychiatric populations: Anxiety and the need for well controlled and validated facial emotional expressions.

As previously mentioned, research on the recognition of dynamic expressions of emotion is scarce, despite the advancements with static stimuli. The same is true with psychiatric populations where less is typically known about how emotions are processed and recognized. Techniques that have generated good data in normal populations such as classification image experiments (e.g., *Bubbles*) are needed before embarking on the more complex quest of elucidating the cognitive and neurological processes underlying the recognition of dynamic expressions. The same applies to the stimuli used to elucidate the cognitive processes involved: appropriate stimuli will be needed to study both static and dynamic facial expressions. That is the use of different form of stimuli (schematic drawings, intense static expressions, morphed stimuli) will only add confusion to an already confused literature. Combining solid methodologies with well controlled and validated static stimuli, as those presented in study 1, will provide much needed information about the use of information in these populations.

For the field of anxiety, the subject of this thesis, the picture is relatively complex due to multiple subtypes of anxiety and the existence of co-morbid conditions such as depression. Are anxious people better or worse than controls at recognizing facial expressions? Does this change as a function of anxiety type or co-morbid condition? Do the anxious brain process expressions differently? These are still questions that remain to be answered. To do this, techniques that can provide reliable data that is not subject to ceiling or floor effects are needed. In addition, stimuli that are capable of informing us about the recognition of static, and later, dynamic expressions are needed. Characterizing the similarities and differences between different forms of anxiety disorders and whether co-morbid conditions such as depression changes the recognition profile will also be eventually required. As a starting point, the following section focuses on the recognition of facial emotional expressions in individuals in trait anxiety (as opposed to different forms of anxiety disorders).

1.3 TRAIT ANXIETY AND EMOTION RECOGNITION

Anxiety has been shown to influence individuals' ability to recognize facial emotional expressions (Hunter, Buckner, & Schmidt, 2009; Langner, Becker, & Rinck, 2009; Philippot & Douilliez, 2005; Richards et al., 2002; Schofield, Coles, & Gibb, 2007; Surcinelli, Codispoti, Montebarocci, Rossi, & Baldaro, 2006) and affect how the brain processes and integrates emotional information (Bruhl et al., 2011; Campbell-Sills et al., 2011; Kim & Whalen, 2009; Spampinato, Wood, De Simone, & Grafman, 2009; Stein, Goldin, Sareen, Zorrilla, & Brown, 2002; Stein, Simmons, Feinstein, & Paulus, 2007). The exact role that anxiety exerts on the process continues to be elucidated. However, it likely varies as a function of symptom severity and subtype (anxiety disorder vs. high trait anxiety in the regular population) (Stein, et al., 2007), despite the high correlation between anxiety disorders (Leary & Kowalski, 1993).

Most of the research on anxiety and emotion recognition is focused on social anxiety and phobia, but the data in these groups is not conclusive. These individuals appear neither better nor worse at recognizing facial expressions (Philippot & Douilliez, 2005; Schofield, et al., 2007), though they seem to require less intensity to recognize anger expressions (Joormann & Gotlib, 2006). They also and tend to use low spatial frequency information in faces that non-anxious participants ignore (Langner, et al., 2009). Finally, eye-tracking data indicate that they tend to look at emotional faces in the first second, but subsequently avoid them. This is consistent with the hyper-vigilance and avoidance hypothesis (Wieser, Pauli, Weyers, Alpers, & Muhlberger, 2009).

Little is known, however, about the association of trait anxiety and emotion recognition. Trait anxiety refers to a stable personality trait that biologically predisposes people to respond fearfully to a wide range of unspecific stressors (Spielberger, O'Neil, & Hansen, 1972), and predisposes individuals to anxiety disorders (Chambers, Power, &

Durham, 2004). Attentional biases to threat related (angry) materials have found in people with high trait-anxiety in a probe-detection task (Mogg & Bradley, 1999). These individuals also tend to classify ambiguous signals (i.e., morphed facial expressions or neutral faces) as fear (Richards, et al., 2002), and perceive various situations as more threatening (Spielberger, et al., 1972). They may also be better at recognizing fear expressions (Surcinelli, et al., 2006), but further exploration is needed (Cooper, Rowe, & Penton-Voak, 2008).

The amygdala-prefrontal cortical circuitry is of particular significance in trait anxiety. It appears that trait anxiety may be associated with reduced prefrontal activity suggesting a weakened recruitment of inhibitory or control mechanisms (Bishop, Duncan, & Lawrence, 2004), whereas state anxiety is related to heightened amygdala and superior temporal sulcus activity (Bishop, 2007; Bishop, Jenkins, & Lawrence, 2007) when perceptual load is low (e.g., when the task doesn’t require all available resources). As suggested, at a cognitive level this could translate in an increased threat related representation and a reduced capacity to control this activation to favour other non-threat related representation.

1.4 THESIS OBJECTIVES

The first objective of this thesis was to develop a validated database of dynamic and static facial emotional expressions adapted for the needs of our laboratory experiments. These stimuli set the stage for the second study, which aims to explore the effect of trait anxiety on the recognition of static facial emotional expressions. The exploration of the effects of trait anxiety on the recognition of dynamic expressions is currently in progress in our laboratory, but is beyond the score of this thesis.

1.5 RESEARCH DESIGN

Two experiments have been conducted in an attempt to meet these thesis objectives. The following sections will provide the rationale and justification for selecting the specific study methods/measures in each experiment.

1.5.1. Article 1. The STOIC facial emotional expressions database: A dynamic and static set of highly recognizable emotions (submitted for publication).

Facial expressions of emotion are highly dynamic in nature. Despite this fact, most studies on facial expressions are conducted using static faces, such as the faces of the widely used set of photographs developed by Ekman & Friesen. Paul Ekman and his collaborators have speculated about distinctive facial features movements (called "facial action units" or FACS) that are important to discriminate facial expressions. The brain regions implicated in the processing facial affect show greater responses to dynamic than to static emotional expressions. In addition, the dynamic properties of facial expressions may improve basic facial expression discrimination. Several databases of dynamic facial expressions exist, but none met the requirements for our studies. We therefore proceeded to create and validate the STOIC database. We recorded actors' expressions in a controlled environment. Selected movie clips (1088) were aligned both spatially, frame by frame, on the average coordinates of the eyes and mouth, and temporally on the last neutral frame before the onset of the expression. The frames containing the apex were used to develop our static expressions. Two separate validations were conducted through participants' rating the intensity of the emotions in all stimuli on continuous scales. The final database contains 80 dynamic and 80 static highly recognizable expressions (fear, sadness, disgust, anger, surprise, happiness, pain, neutrality)

1.5.2. Article 2. Anxiety favours the identification of negative facial expressions (in preparation).

The second article constitutes a first step in the exploration of trait anxiety on emotion recognition. Static emotional expressions, from the STOIC database described above, were used in a *Bubbles* experiment to characterise the use of information in individuals varying in level of trait anxiety. The rational for using only static expressions in this phase of the project is twofold: First, we wanted to provide a benchmark from which past and future studies could be compared. To the best of our knowledge, no studies have attempted to characterize emotion recognition abilities in individuals with high or low trait anxiety using a classification image experiment (e.g. *Bubbles*), and a full range of standardized and validated emotion expressions. A recent study employed *Bubbles* in a group of socially anxious individuals, but used only anger and neutral expressions. Anxious participants were as good as controls, but used low spatial frequency (LSF) information to recognize anger, thus showing a processing bias towards LSF information. We sought to expand on these findings by looking at trait anxiety.

2. ARTICLE 1

Roy, S., Roy, C., Ethier-Majcher, C., Fortin, I., Belin, P., Gosselin, F. (submitted). The STOIC facial emotional expression database: A set of dynamic and static faces expressing highly recognizable emotions.

ABSTRACT

Thirty-four actors expressed facial emotions (fear, happiness, surprise, anger, sadness, disgust, neutrality and pain. Several thousand short videos were recorded and the most 1,088 most promising were selected and later rated by participants with respect to how intensely each stimulus expressed various emotions. The duration of these clips is 500 ms (15 frames), begin with a neutral frame and end on an emotional frame. All faces occupy the same space. Each clip was aligned across frames using points placed on three robust facial landmarks (the pupil centers and the tip of the nose). The frame containing the peak of the expression was extracted from each video to create static stimuli. The STOIC database is comprised of 80 dynamic and their corresponding static images that were most consistently recognized by observers. It showcases five male and five female actors.

Keywords: Dynamic facial expressions, face processing, emotions, database.

Facial emotional expressions communicate information from which we can quickly infer the state of mind of our peers, and adjust our behaviour accordingly (Darwin, 1872). Most psychophysical studies on facial expressions have been conducted using photographs. Photographs are easier to manipulate, but they neglect the dynamic nature of non-verbal communication. Several lines of research have shown that we differentially process static and dynamic emotional expressions. For example, neuroimaging studies show that the brain regions involved in processing of facial affect (and face processing in general) such as the posterior superior temporal sulcus (pSTS), the amygdala, and insula respond differently to dynamic emotional expressions (Haxby, et al., 2000; LaBar, et al., 2003; Sato, Kochiyama, Yoshikawa, Naito, & Matsumura, 2004). In addition, lesions to the brain can alter normal processing of facial emotional expressions. Humphreys, Donnelly and Riddoch (1993) described a patient who could accurately recognize emotional expressions from moving points of light, but not from static images; and, reciprocally, Adolphs et al., (2003) described of a patient who could only recognize dynamic emotional expressions.

The role played by dynamic features in the recognition of facial expression of emotions is still largely unknown (Ambadar, et al., 2005). Some researchers have proposed that motion itself is a powerful cue (Bould & Morris, 2008). Others have postulated, using morphing techniques, that velocity and representational momentum are important factors in the perception of expressions (Yoshikawa & Sato, 2008).

Several photo databases of facial expressions are available, such as the popular set developed by Ekman and Friesen (1975) (e.g., CAFE, Karolinska Directed Emotional Faces). Likewise, there are a few video databases of facial expressions available (Battocchi & Pianesi, 2004; Cohen, Sebe, Garg, & Huang, 2002; Douglas-Cowie, Cowie, & Schroder, 2000; Kanade, et al., 2000; Martinkauppi, Soriano, Huovinen, & Laaksonen, 2002; O'Toole et al., 2005; Pantic, Valstar, Rademaker, & Maat, 2005; Sun, Sebe, Lew, & Gevers, 2004; Wallhoff, 2006). None of these databases are perfectly adapted to the experiments that we plan to carry out (e.g., classification-image and gaze-tracking experiments which require relatively fixed positioning of facial features across frames, clips and actors). While we acknowledge that a handful of databases could have been adapted (i.e., aligned), they were difficult to obtain and also lacked vocal emotional content(Belin, Fillion-Bilodeau, & Gosselin, 2008). As such we created our own set of stimuli with the following characteristics.

1. The database includes both videos and photos (extracted from these videos).
2. The database includes eight facial expressions (fear, anger, sadness, surprise, disgust, happiness, pain and neutrality). The choice of these emotions was based in part of the work of Paul Ekman regarding the universal recognition of the basic emotions. Pain expressions were used as some researchers in our laboratory wished to study the emotion. Whether or not to consider pain as a basic emotion is beyond the scope of

this paper, though the capacity to feel pain (Williams, 2002) and to recognize it in others may be just as important as any basic emotions for our survival (Craig, 2004) and has useful clinical implication (i.e. recognizing pain behaviour in patients).

3. The static stimuli as well as every frame of the dynamic stimuli were spatially aligned—and, in the case of the dynamic stimuli, temporally aligned—thus insuring a consistent positioning of facial features on the screen and minimizing head and body movements. This characteristic of the database will greatly simplify the analysis of classification-image and gaze-tracking data.
4. Over one thousand videos and photos were validated independently. In contrast to what is typically done, we put each stimulus in the perceived emotion category—not necessarily the emotion that the actor intended to express. Only the stimuli that led to the greatest consensus among observers were kept.
5. The database is suitable for face identification (10 actors, each expressing facially the seven emotions and neutrality) and gender discrimination (half of the actors are females), in addition to facial expression recognition. More details about the STOIC database are provided in the following pages.

METHODS

Stimuli creation.

Actors. A total of 34 actors (16 females) between the ages of 20 and 45 years were recruited among theatrical schools in Montreal, Quebec. Actors are typically more experienced in the art of emotion expression than individuals who are not trained in the art of acting. We therefore reasoned they could produce genuine expressions. To ensure some uniformity between the visual stimuli, actors were asked not to wear jewellery, or have facial piercing. Powder was used to reduce sweating and reflecting light and a hairnet ensured that hair would not get in the way.

Filming. Actors were asked to facially express the six basic emotions (happiness, disgust, fear, anger, sadness, and surprise) as well as pain and neutrality. Filming took place in a semi-anechoic chamber with chroma-key blue background, equipped with two diffuse tungsten lamps. The movie streams were recorded using a Canon XL1S video camera. Data was digitally transferred to a Personal Computer (AMD 1700 processor) and captured using Adobe Premier Pro software. The videos were captured in color at a rate of 29.97 images per second with a resolution of 720 by 480 pixels. The actors were positioned 1.5 meter from the lens of the camera and centered in the image. We de-interlaced the video track using a blending method. At the beginning of each recording, actors were asked to hold a Kodak colors chart to allow color and luminance calibrations. However, the validation was done only on the achromatic stimuli. Chromatic stimuli remain available for further studies. Each recording session lasted approximately one hour; actors had to generate multiple exemplars (up to fifty) of the eight facial expressions at different intensities (weak, moderate, high). Actors were asked to say “ah” when expressing the emotions. The audio track was removed for the current validation but remains available for further studies (see Belin, et al., 2008).

Movies and photos. The video track was initially segmented into one-second movies, including the full rise of the facial expressions. This resulted in the creation of approximately 10,000 movie clips. The authors' performed an initial selection (four graduate students listed above). The clips that contained too much body or head displacements were eliminated by four of the authors. Minimizing movements was necessary for the experiments we are conducting. The remaining subset was examined for both authenticity and intensity. In sum, four exemplars (two with low and two with high intensity) with the highest inter-rater agreement were chosen for each emotion and participant (34 actors * 8 emotions * 4 exemplars = 1,088 movies) and included in the validation. For each 1,088 movie clips, we isolated facial-muscle movements by aligning three robust facial features using home-brewed Matlab programs. Thus, for each frame of every movie, three points were positioned, by human observers, on the centers of the pupils and on the tip of the nose. Then, we translated, rotated, and scaled the landmark positions of each frame of each movie to minimize the mean square of the difference between them and a template (see Figure 1; (see Gonzalez, Woods, & Eddins, 2002).

--------Insert Figure 1 about here --------

This template was the average of the landmark positions across all frames and movies scaled so that inter-ocular distance was 100 pixels. A consequence of this spatial alignment is that facial features can be ascribed to a coordinate. The frames were cropped at 256 x 256 pixels, centered on the aligned nose landmark. Movies were also aligned temporally by annotating the last neutral frame prior the appearance of the emotional expression and were shortened to 15 frames (500 ms). Our static expressions consisted of the apex of every movie. We've added mid-gray elliptical masks to the movies (and photos) convolved with a Gaussian filter having a standard deviation of 2 pixels to remove sharp edges. These masks were fitted by emotions and by subjects, and when necessary, individually.

Validation

We then proceeded to the separate validation of our two sets of stimuli (1,088 movies and 1,088 images) to ensure that our final subsets or databases were highly recognizable.

Participants. Thirty-five participants (20 females) from Montreal were recruited for the validation dynamic expressions (mean age and education 25 & 16 years). Thirty-five others (19 females) also from Montreal participated in the validation of the static expressions (mean age and education 23 & 16). All participants reported normal or corrected vision.

Procedure. The validation phase took place in a quiet computer room at the University of Montreal. All 1,088 movies (and 1,088 photos) were presented using the

Internet browser Firefox 2 on Macintosh G5 computers; our website was programmed PHP/JavaScript. Photos were presented for 500 ms, that is, the same duration as the movies. Movies and photos were preceded and followed by mid-gray frames. Data was automatically saved on a Macintosh server's MySQL database. Participants were told they would see several movies (or photos) of actors expressing facially one of eight possible emotions (i.e., fear, happiness, anger, disgust, pain, sadness, surprise, and neutrality). They could view the stimuli a second time if they felt it was necessary. Participants were instructed to rate each stimulus with respect to how intensely they felt the expressed emotion, using seven continuous scroll bars (from leftmost = "not at all" to rightmost = "the most intense possible"). If they perceived an ambiguous facial expression, they were instructed to rate the movie on more than one scroll bar. If they perceived neutrality, they were asked to simply set all scroll bars to the leftmost position.

Stimulus entropy. We measured ambiguity by computing the entropy (E) of their scroll bar ratings: $E = -\sum_i \frac{p_i}{\sum_i p_i} \log_2 \left(\frac{p_i}{\sum_i p_i} \right)$ where p_i is a proportion derived from the scroll bar ratings of emotion i. A stimulus with an entropy of 0 bit was always given a non-zero rating on a single emotion scroll bar—it's as unambiguous as it can be; and a stimulus with an entropy of 2.80 bits was given equal ratings, on average, on all emotion scroll bars—it's as ambiguous as it can be. In preparation for the computation of the proportions (p_i), the scroll bar ratings were transformed into z-scores for every participant. This transformation ensures that a conservative participant that used only the first third of the scroll bars, for example, is comparable to a blasé participant that used only the second third of the scroll bars and to an ideal participant that used the entire scroll bars; but, importantly, it preserves the relative rating differences between emotions. Then, the mean of the z-scores across participants but within emotion (z_i) were transformed into p_i as follows: $p_i = \frac{z_i}{2 \times \max(|z_i|)} + 0.5$

RESULTS

We categorized each movie and photo as a member of the emotion for which it received the highest p_i. Overall, one movie from the final selection was put in the pain category because participants rated the movie highest on the pain dimension even though the actor's intention was to express sadness. Likewise, another movie from the final selection was put in the surprise category even though the actor intended to express neutrality. Interestingly, with the exception of these two clips, the remaining stimuli were recognized appropriately. The only exception to this "max" rule was the neutrality category: a movie (or a photo) was categorized as neutral if $\max(p_i)$ was smaller than criteria including 1/8 of the movies (or photos).

The final subset of stimuli, the STOIC database, comprises the 80 movies (and 80 corresponding photos) associated with the smallest entropy values. These were the most consistently recognized and show case five male and five female actors, each expressing facially all basic emotions, pain, and neutrality. Please note that the remaining clips will also be made available to the scientific community. Tables 1 and 2 show the entropy values of both dynamic and static stimuli. See also Figures 2, 3, and 4 for their proportions derived from the scroll bar ratings - p_i.

We performed basic statistics to help further characterize our databases. A 3-way ANOVA (actor gender x stimuli type x emotion) on the entropy values revealed no significant difference between dynamic and static stimuli or male and female actors. However, as expected, a statistically significant effect of emotion was found ($F_{(6,140)} = 30$, $p < .001$). Emotions such as happiness are always easier to recognize than other emotions such as fear. Tukey post-hoc comparisons showed that entropies for fear and pain emotions are significantly larger ($p < .001$) than those for all other emotions—indicating that fear and pain were the most difficult emotions to recognize—but did not differ from one another (*ns*). Happiness and anger were the easiest emotions to recognize and did not differ from one another (*ns*). Moreover, the entropy values for disgust, sadness, and surprise did not differ from one another (*ns*) and constituted moderately difficult emotions to recognize.

With regards to the confusability of emotions, which can be inferred from the mean rating proportions (see figure 1 and 2), the following patterns emerge. When presented with fear stimuli, raters had a tendency to report some element of surprise. The same was true for surprise stimuli, which contained an element of fear. Pain stimuli contained some sadness and disgust information, sadness stimuli contained pain information, and disgust stimuli contained pain, anger and sadness information.

--------Insert Figure 2 about here --------

--------Insert Figure 3 about here --------

--------Insert Table 1 about here --------

--------Insert Table 2 about here --------

--------Insert Figure 4 about here -------

DISCUSSION

We introduced a validated, and highly recognizable (as measured by entropy ratings), set of dynamic and static facial emotional expressions, which differs significantly from existing databases of facial emotional expressions. To the best of our knowledge, no facial emotional expression database contains the characteristics of our stimuli. This includes the presence of both static and dynamic stimuli, a spatial and temporal alignment of stimuli, an equal number of male and female actors, and eight expression types (fear, happiness, surprise, disgust, anger, sadness, neutrality, and pain).

The final database demonstrated no significant differences between static and dynamic faces or between female or male actors. At first glance, this may appear counterintuitive, however, it should be noted that one of our initial goals was to develop comparable static and dynamic stimuli and that one of the selection criteria from the global set of expressions was that they are recognized equally well in both conditions. It was not uncommon to see static or dynamic stimuli being better recognized in a given category. In fact, an independent t-test between the original stimuli (1088 x 2) revealed that static expressions are better recognized than dynamic expressions t(2174) = t-5.53, p = <0.01. The mean entropy score of static expressions was 1.06 (SEM=0.17), while that of dynamic stimuli was 1.2 (SEM=0.18). Though a proper interpretation is difficult (e.g., some stimuli being excluded from the final database for not being appropriately recognized) it does raise the question: could static stimuli facilitate emotion recognition in the normal population? If so, could it be that presenting the apex of the stimuli for half a second instead of half-second movie clip improve recognition?

One possibility is that the nature of the stimuli, which is relatively short (15 frames), and the task itself (a grey mask immediately followed each presentation) influenced the data in such a way to penalize the contribution of movement. It might be that, despite the high recognition rates, artificially shortening the stimuli to 500ms influenced recognition mechanisms. Considering the research on velocity and representational momentum discussed earlier it would also be interesting to explore the findings obtained in other databases. A recent study conducted in our laboratory with the same stimuli (final database) suggests that greater efficiency is achieved with static as opposed to dynamic stimuli (Hammal, et al., 2009). Whether or not dynamic stimuli are better recognized than static stimuli, however, is in our opinion superfluous, as dynamic stimuli are more ecological and also processed differently by the brain.

We also inferred confusion patterns from participants' ratings. Interestingly, static and dynamic expressions yielded very similar recognition patterns. Our happy and angry expressions in both conditions were extremely well recognized. This is reflected in each entropy value and the relative lack of confusion of the target emotions with other emotions. Happy expressions are well recognized across most studies. This could be due the valence as happiness is the only positive expression. The signal itself is very unique as it is the only expression where the lips are pulled upward (AU12) (Ekman & Friesen, 1975). While anger also communicates unique information (AU23: Lip tightner & AU24: Lip pressor), this expression is less consistently recognized in other databases (e.g., Cohn-Kanade Dataset (LUCEY, COHN et al 2010) and may possibly be related to the quality of the expression (i.e., a signal problem), as opposed to participants' difficulty in decoding the expression.

While fIn contrast, fear was relatively difficult to recognize (higher entropy values) compared to other emotions as it was most often confused with surprise expressions (and vice versa). This is a very common finding in the literature. This finding is nevertheless intriguing considering the expressions are very different (e.g., **surprise**: brows raised high and curved; Horizontal wrinkles on forehead; jaw is dropped. **fear**, upper eyelids are raised, the lower ones are tensed and the sclera is exposed (Ekman & Friesen, 1975).

This observation is further supported through the use of an ideal observer and the *Bubbles* method whereby a computer system uses variations contained in the expressions to reveal the best possible performance. Using this technique, Schyns et al., (2009) that little correlation exists between expressions. Confusion might occur because the perceiver experiences difficulty disambiguating the two expressions (the eyes and mouth are involved in both) or experiences other forms of interference (fear and surprise causing more arousal ratings than other emotions) (Simon, Craig, Miltner, & Rainville, 2006)

With regards to disgust and sadness, which were well recognized in our database, some confusion was observed in both static and dynamic condition with pain. From an informational standpoint, too little is known about what information is transmitted or used during perception to recognize pain expressions. One possibility is that overlapping information is communicated between all three expressions that are perceived as pain expressions. A second possibility is that the pain expression was difficult to perceive because pain was also contained sadness and disgust information.

Concluding remarks.

A new database containing dynamic and static emotional expressions was created. The database has been validated and has potential to benefit both researchers and clinicians. The database differs from others in several ways as it contains natural and highly controlled expressions. The inclusion of pain expressions, which is unique to our database, will undoubtedly be valuable for future research on empathy. As well, it can be useful in clinical settings to better understand pain behaviour. For example, clinicians may be better able to assess whether an individual is experiencing physical pain and treat accordingly. Finally, our stimuli provide an excellent tool for image classification or eye tracking experiments. They are also freely downloadable.

Figure 1. Left: Mean of all frames of a fear movie pre-alignment superimposed with the position of the facial landmarks annotated in red and the average facial landmarks in green. A dynamic version is available here. Right: The same but post-alignment: A significant amount of smear has been removed. A dynamic version is available here.

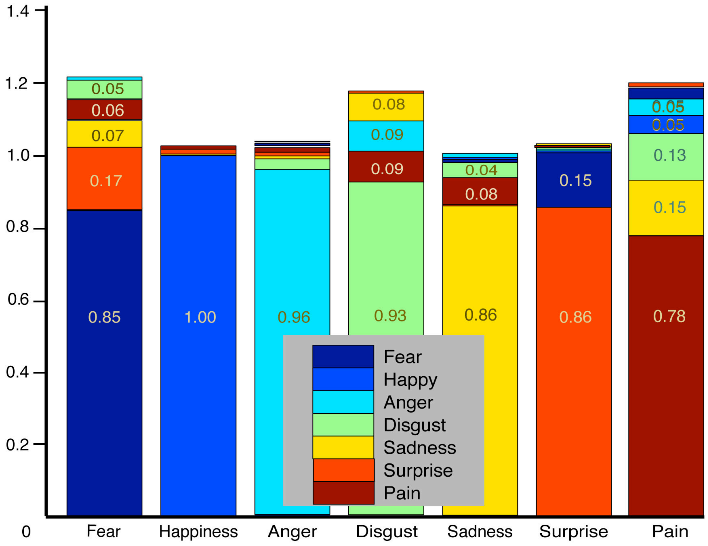


Figure 2. Mean rating proportions (p_i) for photos. The graph clearly illustrates that all emotions were very recognizable. Happiness and anger contained very little ambiguity. Pain and fear, however, though relatively well recognized were more ambiguous to the raters.

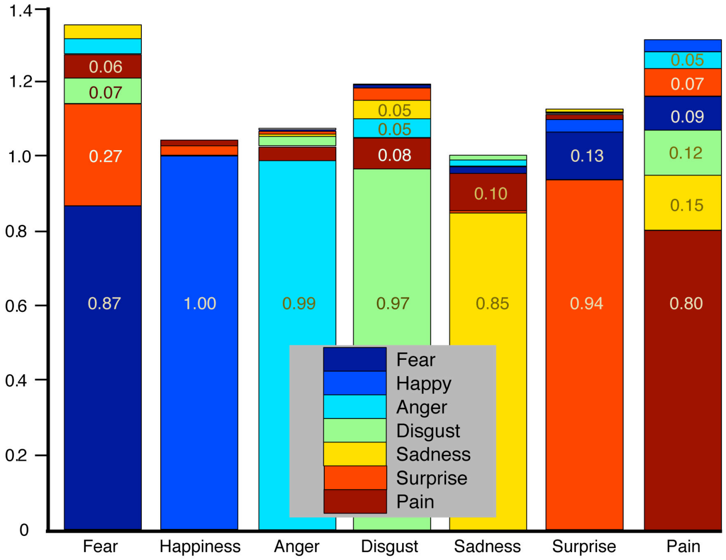
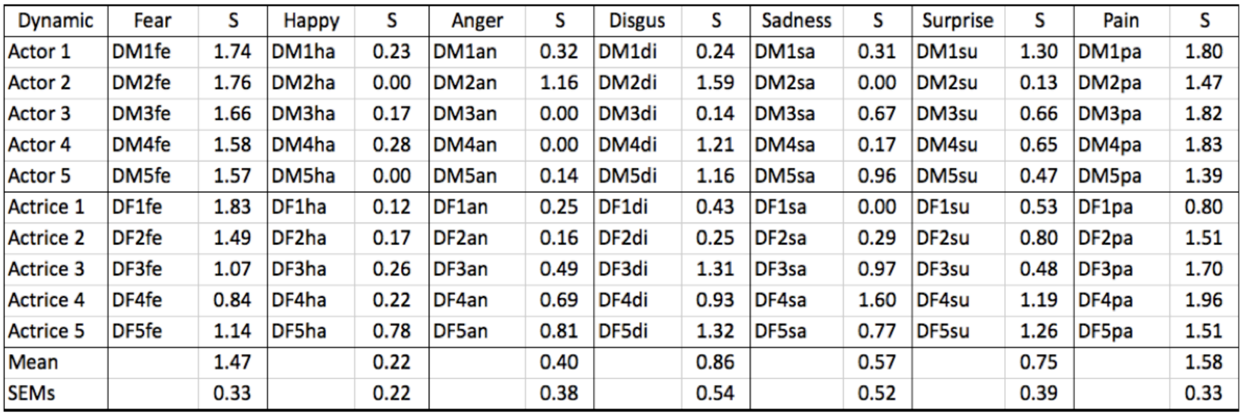


Figure 3. Mean rating proportions (p_i) for movies. The graph clearly illustrates that all emotions were very recognizable. Happiness and anger contained very little ambiguity. Pain and fear, however, though relatively well recognized were more ambiguous to the raters.

Table 1

Entropy values of the dynamic stimuli

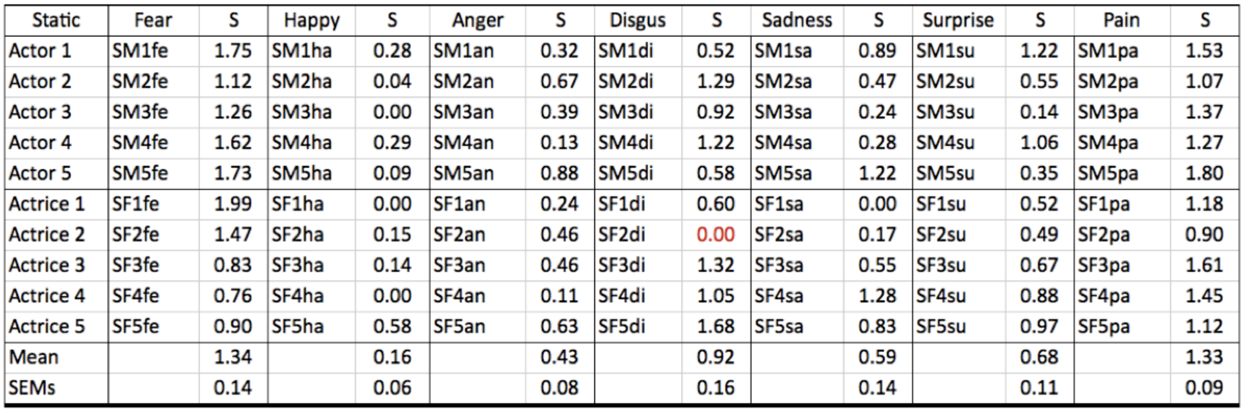


Dynamic	Fear	S	Happy	S	Anger	S	Disgus	S	Sadness	S	Surprise	S	Pain	S
Actor 1	DM1fe	1.74	DM1ha	0.23	DM1an	0.32	DM1di	0.24	DM1sa	0.31	DM1su	1.30	DM1pa	1.80
Actor 2	DM2fe	1.76	DM2ha	0.00	DM2an	1.16	DM2di	1.59	DM2sa	0.00	DM2su	0.13	DM2pa	1.47
Actor 3	DM3fe	1.66	DM3ha	0.17	DM3an	0.00	DM3di	0.14	DM3sa	0.67	DM3su	0.66	DM3pa	1.82
Actor 4	DM4fe	1.58	DM4ha	0.28	DM4an	0.00	DM4di	1.21	DM4sa	0.17	DM4su	0.65	DM4pa	1.83
Actor 5	DM5fe	1.57	DM5ha	0.00	DM5an	0.14	DM5di	1.16	DM5sa	0.96	DM5su	0.47	DM5pa	1.39
Actrice 1	DF1fe	1.83	DF1ha	0.12	DF1an	0.25	DF1di	0.43	DF1sa	0.00	DF1su	0.53	DF1pa	0.80
Actrice 2	DF2fe	1.49	DF2ha	0.17	DF2an	0.16	DF2di	0.25	DF2sa	0.29	DF2su	0.80	DF2pa	1.51
Actrice 3	DF3fe	1.07	DF3ha	0.26	DF3an	0.49	DF3di	1.31	DF3sa	0.97	DF3su	0.48	DF3pa	1.70
Actrice 4	DF4fe	0.84	DF4ha	0.22	DF4an	0.69	DF4di	0.93	DF4sa	1.60	DF4su	1.19	DF4pa	1.96
Actrice 5	DF5fe	1.14	DF5ha	0.78	DF5an	0.81	DF5di	1.32	DF5sa	0.77	DF5su	1.26	DF5pa	1.51
Mean		1.47		0.22		0.40		0.86		0.57		0.75		1.58
SEMs		0.33		0.22		0.38		0.54		0.52		0.39		0.33

Note. Stimuli names (e.g., "DM1fe") have the following format: Dynamic or static (e.g., "D or S"), gender of the actor (e.g., "M or F"), actor number (e.g., "1"), the first two letters of the expression (e.g., "fe" = "fear").

Table 2

Entropy values of the static stimuli



Static	Fear	S	Happy	S	Anger	S	Disgus	S	Sadness	S	Surprise	S	Pain	S
Actor 1	SM1fe	1.75	SM1ha	0.28	SM1an	0.32	SM1di	0.52	SM1sa	0.89	SM1su	1.22	SM1pa	1.53
Actor 2	SM2fe	1.12	SM2ha	0.04	SM2an	0.67	SM2di	1.29	SM2sa	0.47	SM2su	0.55	SM2pa	1.07
Actor 3	SM3fe	1.26	SM3ha	0.00	SM3an	0.39	SM3di	0.92	SM3sa	0.24	SM3su	0.14	SM3pa	1.37
Actor 4	SM4fe	1.62	SM4ha	0.29	SM4an	0.13	SM4di	1.22	SM4sa	0.28	SM4su	1.06	SM4pa	1.27
Actor 5	SM5fe	1.73	SM5ha	0.09	SM5an	0.88	SM5di	0.58	SM5sa	1.22	SM5su	0.35	SM5pa	1.80
Actrice 1	SF1fe	1.99	SF1ha	0.00	SF1an	0.24	SF1di	0.60	SF1sa	0.00	SF1su	0.52	SF1pa	1.18
Actrice 2	SF2fe	1.47	SF2ha	0.15	SF2an	0.46	SF2di	0.00	SF2sa	0.17	SF2su	0.49	SF2pa	0.90
Actrice 3	SF3fe	0.83	SF3ha	0.14	SF3an	0.46	SF3di	1.32	SF3sa	0.55	SF3su	0.67	SF3pa	1.61
Actrice 4	SF4fe	0.76	SF4ha	0.00	SF4an	0.11	SF4di	1.05	SF4sa	1.28	SF4su	0.88	SF4pa	1.45
Actrice 5	SF5fe	0.90	SF5ha	0.58	SF5an	0.63	SF5di	1.68	SF5sa	0.83	SF5su	0.97	SF5pa	1.12
Mean		1.34		0.16		0.43		0.92		0.59		0.68		1.33
SEMs		0.14		0.06		0.08		0.16		0.14		0.11		0.09

Note. Stimuli names (e.g., "SM1fe") have the following format: Dynamic or static (e.g., "D or S"), gender of the actor (e.g., "M or F"), actor number (e.g., "1"), the first two letters of the expression (e.g., "fe" = "fear").

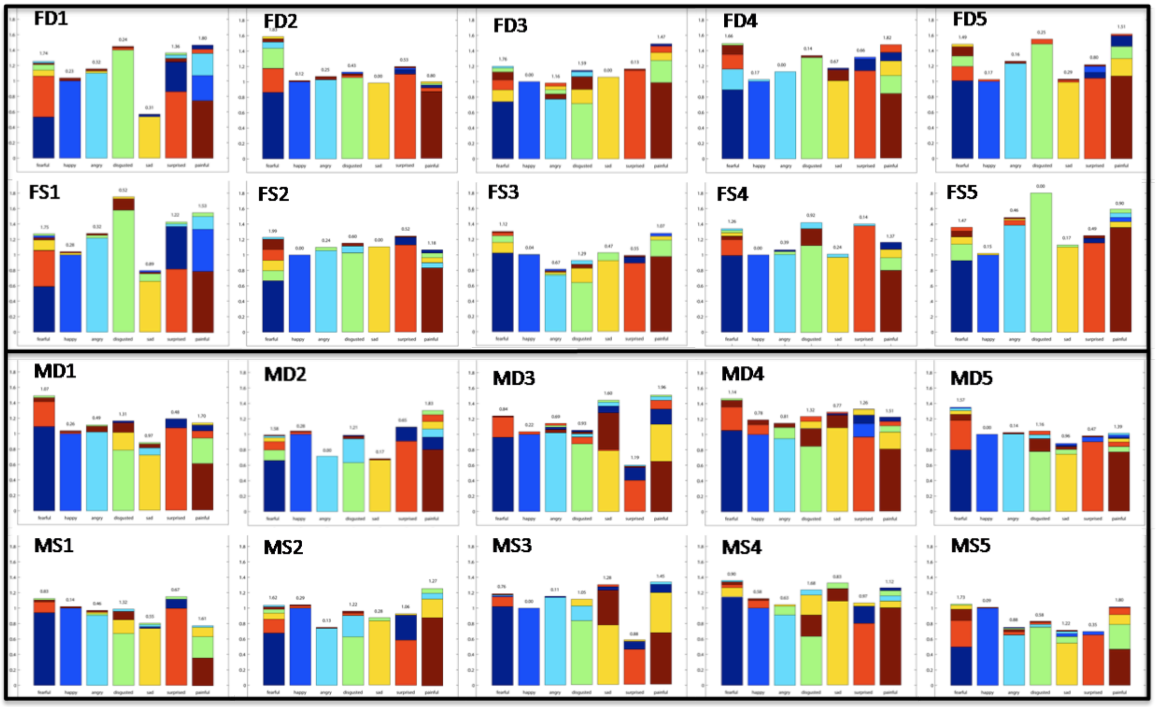


Figure 4. Mean rating proportions (p_i) for all photos and movies for female (top) and male (bottom) actors. F and M stand for Female and Male respectively. S and D stand for static and dynamic respectively. Finally one through five is the female or male actor number.

3. ARTICLE 2

Bacon, B*., Roy, S*., McCabe, E., Dugas, M. J., Gosselin, F. (in preparation).

Anxiety favours the identification of negative facial expressions *Shared 1st co-authorship.

ABSTRACT

We show that symptoms associated with anxiety favours the correct identification of negative facial expressions. Participants varying in trait anxiety were shown faces hidden behind bubble masks and asked to identify the correct emotion. As subject anxiety increased, bubbles needed to maintain 75% correct response rate decreased. Multiple regression over 139,000 total trials shows that anxiety led to more efficient information use for all the negative emotions, but not for happy and neutral expressions. Our findings extend prior findings demonstrating that anxiety is not only associated with a bias for low spatial frequency information, but also a tendency to use information around the mouth region and better fear recognition. Additional analyses reveal that the shared variance between anxiety and depression is most strongly associated with performance. This shared variance has been discussed elsewhere and associated with the concept of neuroticism.

Keywords: STOIC, emotions, fear, trait anxiety, *Bubbles.*

It is generally accepted that anxiety causes biases in visual perception, particularly with regards to social stimuli such as faces. For example, it has been shown that socially anxious individuals demonstrate an attentional bias towards negative facial expressions (Heinrichs & Hofmann, 2001; Mogg & Bradley, 2002) and that they also tend to classify neutral expressions as being negative (Richards, et al., 2002).

Anecdotal evidence suggests that anxiety would facilitate the identification of negative emotions, but empirical evidence is lacking. A recent study (Langner, et al., 2009) has used *Bubbles* (Gosselin & Schyns, 2001; Smith, et al., 2005) to show that socially anxious individuals make better use of low-spatial frequency information to identify angry (vs. neutral) facial expressions, but no improvements in performance with anxiety level were found. This is counterintuitive since better use of information should translate into better performance. The forced-choice nature of their task (angry vs. neutral) may have restricted the possibility of performance enhancement. The present study assesses the role of trait anxiety on the identification of negative facial expressions with an array of eight expressions (fear, happiness, sadness, disgust, surprise, anger, pain and neutrality). This effectively removes the “forced-choice” aspect of Langner et al. (2009).

Trait anxiety was studied because it is regarded as a risk factor for (Chambers, et al., 2004; Naragon-Gainey, 2010), and correlated with, anxiety disorders (Leary &

Kowalski, 1993). In addition, data from image classification experiments such as *Bubbles* will complement recent brain research on the topic.

Trait anxiety is considered to be a general predisposition to respond fearfully to a wide range of unspecific stressors (Spielberger, et al., 1972). Attentional biases to threat related (angry) materials have found in individuals with high trait-anxiety in a probe-detection task (Mogg & Bradley, 1999). These individuals also tend to classify ambiguous signals (i.e., morphed facial expressions or neutral faces) as fear (Richards, et al., 2002), and perceive various situations as more threatening. Finally, it may be associated with better recognition of fearful expressions (Surcinelli, et al., 2006).

The amygdala-prefrontal cortical circuitry is of particular significance in trait anxiety. Trait anxiety appears to be associated with reduced prefrontal activity, which may indicate the presence of impoverished control or inhibitory mechanism over amygdala function (Bishop, et al., 2004). State anxiety, however, is related to heightened amygdala and superior temporal sulcus activity (Bishop, et al., 2007). At a cognitive level this could translate in an increased threat related representation and a reduced capacity to control this activation to favour other non-threat related representation.

METHODS

Participants. Twenty-seven students (19 females; aged 20 to 25) from Bishop's University and the Université de Montréal participated in the experiment. All participants had normal or corrected-to-normal vision. They received course credit or were compensated for their participation.

Stimuli. We used the static stimuli of the STOIC database (Roy et al., 2007). The database consists of 80 exemplars (5 females + 5 males) * 8 facial expressions, which include facial expressions of the six basic emotions (fear, happiness, surprise, sadness, disgust, anger), as well as pain and neutrality. The emotions were expressed by trained actors and were found to be highly recognizable. All exemplars are aligned and shown in grayscale of normalized luminance and variance.

Procedure. Participants were seated 1 m in front of a 21-inch CRT display in a dimly lit room. Images (256 x 256 pixels; 5.72 x 5.72 degree of visual angle) were shown one at a time, at the center of the screen and remained on the screen until the subject pushed one of eight buttons corresponding to the 8 shown emotions (fear, happiness, surprise, sadness, disgust, anger, pain and neutrality). Base faces were drawn randomly from 80 exemplars and their mirror images (for a total of 160 base images), and randomly sampled using Gaussian apertures in the two-dimensional image plane and in five spatial frequency bands (see Gosselin & Schyns, 2001; Smith et al., 2005). Each subject completed a mean of 2,572 trials (*std*=1,195; minimum=1,600; maximum = 4,000).

RESULTS AND DISCUSSION

The number of Gaussian apertures was varied on a trial-by-trial basis to maintain performance as close as possible from 60% correct using the QUEST algorithm (Watson & Pelli, 1983) to minimize the risk of floor and ceiling effects (mean number of Gaussian apertures=114; *std*=53; maximum=289; minimum=60). Two subjects were considered outliers, as they needed a number of Gaussian apertures more than the mean plus 1.65 times the standard deviation (204 and 289). They were excluded from further analyses, and this brought the statistics of the number of Gaussian apertures to: mean=104; *std*=37; minimum=53; maximum=192.

Participants completed the State-Trait Anxiety Inventory (Form Y), *trait version* (STAI-T; Spielberger, 1977). It is a 20-item measure of individual differences in anxiety proneness or trait anxiety. Each item is rated on a 4-point scale, ranging from 1 (almost never) to 4 (almost always). The STAI-T has high internal consistency in anxiety disorder samples, a = .89, and has been shown to reliably distinguish between patients with anxiety disorders and nonclinical controls (Bieling, Antony, & Swinson, 1998). On average, our participants obtained a score of 37.64 (*std*=9.62; maximum=56; minimum=21). Participants also completed the *Beck Depression Inventory II* (BDI-II; Beck, Steer, & Brown, 1996). It includes 21 groups of 4 items reflecting different degrees of depressive symptoms (e.g., sadness, pessimism, loss of interest). Respondents indicate which item within each group best describes them during the past two weeks, with scores ranging from 0 to 3. The BDI-II has very good internal consistency, a = .92, and excellent test-retest reliability over a one-week period, r = .93 (Beck et al., 1996). The questionnaire also shows evidence of convergent and divergent validity (Steer & Clark, 1997). On average, our participants obtained a score of 7.36 (*std*=6.78; maximum=29; minimum=0). As expected, the Pearson correlation between the two tests was significant (r=0.64; $t(23)$=4.01; p<0.001).

If the QUEST algorithm that adjusted the number of Gaussian apertures worked perfectly, the number of Gaussian apertures required for each individual would be inversely proportional to their sensitivity. However, this procedure is imperfect because of perceptual learning, variability in vigilance over time, the variability in difficulty inherent to the task (i.e., some emotions are easier to identify than others). In fact, the average percentage of correct responses (among the 25 remaining participants) was 61.52 %

(*std*=2.27%; minimum=57.19%; maximum=65.97%). We divided the interval between the maximum and the minimum number of Gaussian apertures used by each subject into 100 equally spaced bins. For each of these bins we computed the correct response rate. Then we best-fitted a cumulative Gaussian function to this data (mean r^2=0.6032; *std*=0.1354) and interpolated the number of Gaussian apertures threshold corresponding to a percentage of hits of 65% (mean threshold=110 Gaussian apertures; *std*=32; maximum=200; minimum= 68).

The Pearson correlation between the number of Gaussian apertures thresholds and the STAI-T scores is -0.43 (t(23)=-2.27; *p*<0.017). In other words, the greater your STAI-T score, the better you are at recognizing facial expression of emotions (the less pieces of information you need to reach 65% correct).

Women have been shown to be better than men at recognizing facial expression of emotions (Collignon et al., 2010). Our data replicates this finding: On average, men required 134 Gaussian apertures to respond correctly 65% of the time (std=16) whereas women required 101 Gaussian apertures (std=32; *t*(20.88)=3.46; *p*<.0024). However, women did not score higher on the STAI-T (mean=39; std=10.06) than men did (mean=34.14; std=7.97; t(13.86)=-1.27; *ns*). This suggests that the findings that participant that scored higher on the STAI-T were required fewer Gaussian apertures to reach 65%

correct cannot be explained by gender differences. More direct evidence for this comes from the Pearson correlations between the number of Gaussian apertures thresholds and the STAI-T scores for women (r=-0.34; t(16)=-1.43; *ns*) and for men (r=-0.64; t(5)=1.87; *ns*), which both show a trend toward our main result—the greater your STAI-T score, the better you are at recognizing facial expression of emotions. While these data are preliminary and our sample size was small, it would be interesting to include additional participants in future studies to confirm that no difference in trait anxiety is accurate considering that previous research has shown that women tend to have higher scores on depression and anxiety measures (Parker & Brotchie, 2010). Increasing the number of subjects, hence the number of trials could also further characterize the profile. It would tell us whether women are better at recognizing all emotions or whether they do better with a subset of these (e.g., fear).

The Pearson correlation between the residuals variance of the STAI-T scores (what was unique to anxiety) became non significant after the variance also explained by the BDI-II scores (overlap between anxiety and depression) has been removed (number of Gaussian apertures thresholds is -0.13 (*t*(23)=-0.63, *ns*). The remainder of the analyses reported in this article will use the STAI-T scores.

The number of Gaussian apertures was adjusted on the overall mean accuracy; mean accuracy varied between emotions. For each participant, we computed a vector of mean accuracies for all emotions and linearly transformed it so that the minimum value was equal to 0 and the maximum value was equal to 1. Finally, we Pearson correlated the STAI-T scores with these linearly transformed accuracies. Only fear attained statistical significance after a Bonferroni correction (r=0.54; $t(23)$= 3.04; p<0.003).

We performed least-square multiple linear regressions on the location of the Gaussian apertures and the accuracy of the subject's response on each trial to pinpoint the facial features that different observers used to identify the various expressions. The plane of regression coefficients yielded by this operation is called a classification image: it reveals which locations on the face image (i.e., which parts or features of faces) are systematically associated with emotion discrimination performance on our task. We computed one such raw classification image per subject per emotion and per band of spatial frequencies.

We first calculated the group of pixelwise classification images per emotion, that is, the effective information used to correctly identify each of the eight emotions regardless of STAI-T scores. We summed individual raw classification images, smoothed the resulting group classification images with the Gaussian filters used to sample the information during the experiment (FWHM=7.0645, 14.1289, 28.2578, 56.5157, from finest to coarsest scales), transformed them into Z-scores, and, to determine whether visual information correlated reliably with accuracy, we applied corrected statistical tests (Pixel test, S_r=25,233 pixels; $p<0.025$; Chauvin et al., 2005). The diagnostic areas for the various emotions confirm what has been obtained in the past using a slightly different stimuli set and a slightly different procedure (Supplementary Figure 1; Smith et al., 2005).

Then we calculated the pixelwise classification images like we did above but for the participants above the median score and for the participants below or at the median STAI-T. To increase signal-to-noise ratio, for each scale and for each anxiety level, we summed the classification images across emotions, and transformed them into Z-scores by dividing by $\sqrt{8}$. Finally, we calculated the difference between these two sets of classification images and transformed the resulting classification images into Z-scores by dividing by $\sqrt{2}$. Figure 1 shows in color the areas that attained statistical significance for the various scales superimposed on a filtered fearful face (Pixel test, S_r=25,233 pixels; $p<0.025$; Chauvin et al., 2005).

--------Insert Figure 1 about here --------

Our findings confirmed and extended the results of Langner et al. (2008) who showed that more anxious individuals are tuned to lower spatial frequencies when compared to less anxious individuals. In the present study, the only significant blob in the difference classification images fall in the 5.3-10.6 cycles per face bandwidth. However, this blob falls within the naso-labial region of the face. This partially contradicts what Langner et al. (2008) have reported (i.e., that the anxious used the eyes/eyebrows/forehead regions more than the nonaxious). It is also counterintuitive given the accuracies of the two groups with fearful faces, which are recognized primarily by the eyes; Smith et al., 2005; Adolphs et al., 2005.

Why are more anxious individuals better at recognizing fear, which depend mostly on the eyes in the high-frequency band? One plausible explanation is because fear is easily confounded with surprise, which rests mainly on the mouth in lower frequency bands. More anxious individuals attend to the mouth of fearful faces, but less anxious individuals do not. This hypothesis was tested by looking at the correlation between the optimal trait anxiety score and surprise false alarm when the face is fearful (r=-0.3464, $t(23)$=-1.7710, p=0.0449. Responding surprised when the emotion is fearful was the most correlated false alarm in the fear row—only the hits are more correlated in the fear row).

Overall, this paper supports the notion that anxiety alters the way individuals process emotional information. Interestingly, this bias is more selective then previously believed. Anxious participants did have a bias for LSF information across negative emotions. However, only fear recognition was associated with anxiety. The nature of this difference and the particular significance of fear is unclear. Recent research suggests that the amygdala could play an important role. First, the amygdala has for some time been linked to fear recognition (Adolphs, Tranel, Damasio, & Damasio, 1995). Second, low spatial frequencies have been shown to reach the amygdala quickly by way of the superior colliculus during the perception of fearful faces (B. Mermillod, Vuilleumier, Peyrin, Alleysson, & Marendaz, 2011; M. Mermillod, Droit-Volet, Devaux, Schaefer, & Vermeulen, 2010; N. Vuilleumier et al., 2006). Third, anxiety has been associated with heightened amygdala activity and reduced frontal lobe control (Bishop, et al., 2007).

On a final note, it would be interesting to characterize the use of information overtime in anxiety. This research is currently underway in our laboratory. It is possible that spatial frequencies and the use of different featural information interact differently with anxiety compared to normal controls. Or it may be that anxious participants process LSF information quickly (during early frames) and HSF information around the eyes (in late frames). This finding would lend support to the idea that the amygdala facilitates quicker, and more, information recognition abilities.

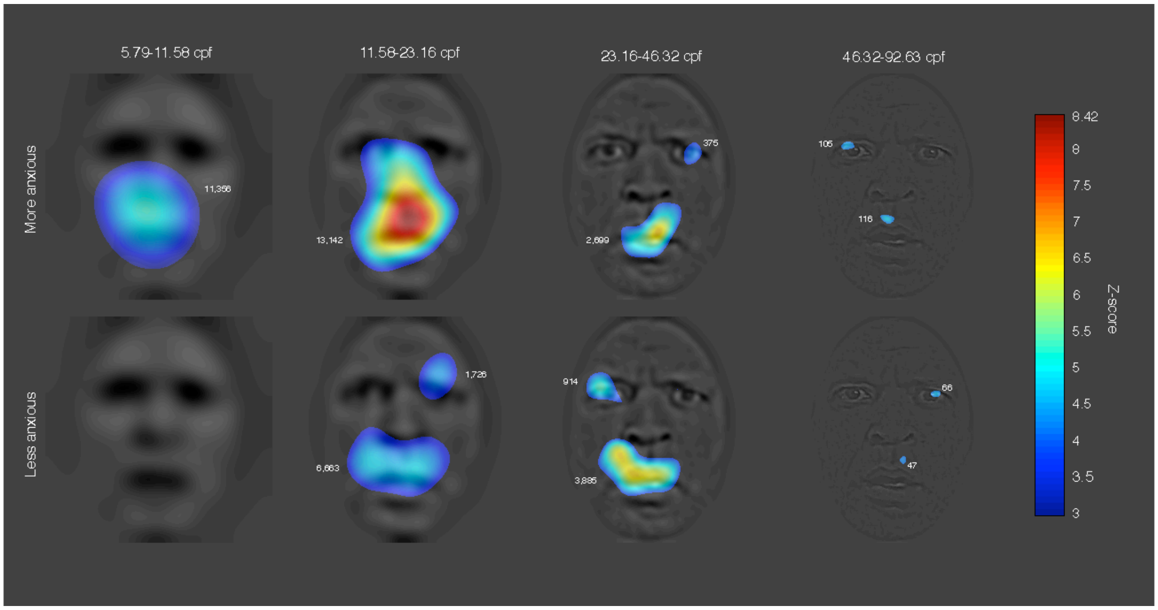


Figure 1. Top: diagnostic information used by anxious participants as a function of spatial frequency bands. Bottom: diagnostic information used by non-anxious participants as a function of spatial frequency bands.

4. DISCUSSION

4.1 MAIN THESIS FINDINGS

The STOIC database is uniquely adapted to experiments requiring the fixed positioning of facial features such as image classification and eye-tracking experiments. The final 80 video clips and corresponding images were very well recognized. The images were used in a *Bubbles* experiment with a group of university students varying in trait anxiety. The association between performance and trait anxiety was examined and classification images were created. Overall, anxiety led to better recognition of negative emotions and a preferential use of low spatial frequency information.

4.1.1. Article 1: Main findings. The main purpose of this study was to validate a set of dynamic and static facial emotional expressions that could be used in other experiments. Some of the database's key features include its rigorous validation process and controlled characteristics such as luminance and fixed positioning of facial features across actors, frames and emotions. The validation process ensured that all emotional expressions communicated the intended emotions and that only the purest stimuli were included in the final database. Entropy values associated with the recognition of static and dynamic stimuli were compared statistically. Stimuli type and gender of actors did not influence intensity ratings. As expected, however, some emotions were better recognized than others. Happiness and anger were the easiest to recognize, followed by disgust, sadness and surprise. Fear and pain were the most difficult to recognize. A confusability matrix was inferred from the mean rating proportions. When participants rated stimuli as fearful, they also had a tendency to report that it contained some element of surprise (and vice versa); that pain contained elements sadness and disgust; that sadness contained elements of pain; and that disgust, contained elements of pain, anger, and sadness.

4.1.2. Article 2: Main findings. We explored the impact of trait anxiety on the recognition of facial emotional expressions. University students with a negative psychiatric history of depression and anxiety disorders were recruited and asked to complete the State-Trait Anxiety Inventory and the Beck Depression Inventory. Results demonstrated that trait anxiety was associated with the use low spatial frequency information around the mouth region, and better performances with the recognition of negative emotions, particularly fear. Anger recognition was not correlated with anxiety. The shared variance between anxiety and depression, or neuroticism, was most strongly associated with performance.

4.2 OVERALL THESIS DISCUSSION

The main objectives of this thesis were:

i. To develop a database of dynamic and static facial emotional expressions.

ii. To explore the association between trait anxiety and emotion recognition.

The following sections provide an integrated discussion of the thesis findings highlighting the nature of better fear recognition in participants who have the tendency to experience more anxiety.

4.2.1 The need for a well-controlled and validated database.

Paul Ekman was one of the first to create an easily accessible, standardized and validated database of emotional expressions. Although, his stimuli continue to remain in circulation, several labs have recently introduced their own stimuli. Many of these databases have trained their actors to express emotions using the FACS system, which leads to the question of what drives facial expression recognition? Our actors were asked to simulate expressions by immersing themselves in past emotional experiences and only the most recognizable stimuli based on participants' intensity ratings were retained. These may or may not conform to FACS.

Additionally, few databases possess the characteristics needed for classification image and eye tracking experiments. The STOIC database was made to address these shortcomings and it also provides researchers a tool to test their hypotheses as they relate to gender and identity recognition and the potential contribution of chromatic information to emotion recognition. It is particularly designed to explore questions as they relate to the perception of dynamic vs. static expressions.

Finally, the database can be used for clinical purposes. Social-emotional difficulties have been reported in various groups including individuals with autism and traumatic brain injuries. Since social understanding relies heavily on the ability to recognize other people's emotions, the STOIC database provides a unique opportunity for clinicians to benchmark patients' performance against a normative sample.

4.2.2 ***Bubbles* and emotions recognition.** Our study empirically demonstrates that trait anxiety is associated with the additional use of low spatial frequency information (LSF) and the recognition of fearful faces, but not angry faces. This would explain why Langner et al., (2009), who used *Bubbles* to explore the effect of anxiety on anger recognition, found that anxiety led to the use of LSF, but not a performance enhancement. The fact that fear holds a special place in anxiety is not surprising considering they are similar constructs with overlapping behavioural, cognitive and physiological components. Anxious individuals appear to use additional information to disambiguate fear from surprise (i.e., mouth region in LSF is known to be used to recognize surprise). Additionally, surprise false alarms when fearful expressions were shown, were negatively correlated with anxiety.

This study also served to replicate Smith et al., (2005)'s study. Despite the similar methodology, our study differed in some respects. First, Smith et al (2005) varied the number of bubbles as a function of individual emotions, while we adjusted the number of bubbles according to the overall performance. While their approach has its appeal as each expression varies in terms of ease of recognisability, the number of bubbles becomes a cue in itself (i.e., less bubbles signals happiness). The danger we faced when adjusting the number of bubbles according to overall performance was that easily recognizable emotions such as happiness and anger could have caused a ceiling effect; however this was not the case. Second, we used a different set of emotional expressions in order to test explore the effects of motion on emotion recognition (these studies are well underway). Third, our study is the first to use painful expressions in a image classification experiment. Overall, despite these differences, our findings are consistent with Smith et al (2005)'s findings demonstrating the reliability of the *Bubbles* method (See figure 1 below).

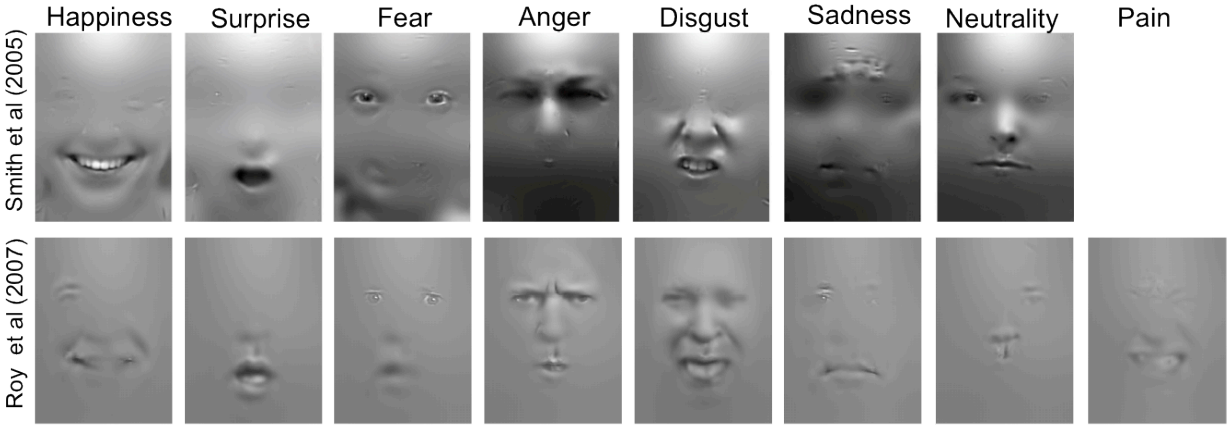


Figure 1. Top: Classification images obtained by Smith et al. (2005). Bottom: Classification images from our study. Note the similarities between the two. Results show that the mouth region in LSF was used to recognize surprise and happiness. The eyes in HSF were used for fear, and in LSF for anger. The nose area in LSD was used for disgust, and the forehead in both LSF and HSF are used for sadness. The eyes and mouth in LSF and HSF was used for pain.

4.2.3 on the nature of better fear recognition. Why is anxiety associated with better fear recognition? The nature of the association between anxiety and performance is not straightforward and the mechanism by which anxiety appears to exert its influence is elusive. One mechanism by which anxiety could influence performance is by incidental learning. Adolphs et. al., (2005) previously demonstrated that patients such as S.M who are impaired at recognizing fear expressions can be taught strategies to recognize the emotion. Paul Ekman has also successfully created a training program aimed at helping people detect micro-expressions and improve recognition accuracy (Elfenbein, 2006; Russel, Chu, & Phillips, 2006).

Anxiety may also simply change the brain’s sensitivity to these signals. The amygdala has already been shown to be sensitive to low spatial frequency information in faces (P. Vuilleumier, Armony, Driver, & Dolan, 2003), and linked to fear recognition (Adolphs, et al., 1995). Anxiety has also been associated with heightened amygdala activity (particularly state anxiety) and reduced frontal lobe control over the structure (particularly in trait anxiety) (Bishop, et al., 2007). The additional use of low spatial frequencies in our anxious participants could be associated increased amygdala activity and thus better performances with fear recognition.

On a final note, it would be interesting to characterize the use of information in time in individuals with high trait anxiety. This research is currently underway in our laboratory. It may be that spatial frequencies and featural information is perceived differently over time. Anxious participants, for example, could process LSF information quickly (during early frames) and HSF information around the eyes (in later frames). This finding would lend support to the idea that the amygdala facilitates quicker and more information recognition abilities.

4.3 MAIN THESIS LIMITATIONS AND FUTURE RESEARCH

One limitation of the *Bubbles* technique is that it has been proposed that the use of induces atypical strategies. For example, showing only parts of the stimulus on any given trial may inadvertently force participants to use this available information, which they would not have used in any normal circumstances (i.e., when the whole stimuli is presented (Murray & Gold, 2004). However, a direct comparison between *Bubbles* and reverse correlation method yielded similar results (Gosselin & Schyns, 2004). In an effort to further reduce the chance of participants' learning strategies to recognize expressions we added multiple expressions (8 instead of 2; i.e., Langner et al., 2009) and adjusted the task difficulty online across emotions, as opposed to presenting an individual emotion basis. Doing this prevented participants from learning, for example, that less bubbles indicates the presence of an easily recognizable emotion such as happiness, while more bubbles would indicate the presence a more difficult emotion to recognize such as fear (i.e. Smith, et al., 2005). For further discussion of this limitation, see (Murray & Gold, 2004) and (Gosselin & Schyns, 2004).

Another limitation of this thesis is the limited amount of emotional and personality measures used in our study. The reason for this is that *Bubbles* requires numerous trials, which requires hours to complete. Adding measures significantly prolongs testing time, which may have led to a decrease in participants' task completion. Moreover, the majority of previous studies also use simple anxiety questionnaires, thus our methodology remained consistent with such studies in this regard.

A third consequence of using the *Bubbles* method, which uses multiple emotions, was that it took approximately 6-8 hours for each participant to complete the task. Increasing the number of participants or reducing the number of emotions could improve the signal to noise ratio and provide more detailed classification images for individual emotions. A cost effective strategy, however, would be to focus on fearful faces as this emotion is particularly significant for anxiety.

Our results showed that the intersection between anxiety and depression, which is likely neuroticism (Griffith et al., 2010), most strongly correlated with performance. Hence, the notion that neuroticism correlates with performance would benefit from further evaluation in future studies. In addition, there might be unique personality and genetic characteristics that may explain anxious individuals' ability to recognize negative emotions. Finally, functional imaging techniques could be used to pinpoint differences in the brains of anxious participants, which might explain their better performances (Chan, Norbury, Goodwin, & Harmer, 2009).

Finally, future studies should explore the use of information in space and time, as this was one of the reasons the STOIC database was created. Our laboratory is currently in the process of elucidating this question in both normal and anxious participants. Results are currently being analyzed and should be published in upcoming months.

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