Linking language and emotion: How emotion is understood in language comprehension, production and prediction using psycholinguistic methods.

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I dedicate this thesis to my mother, who never stopped believing in me even when I don’t.

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Lay Summary

As humans, we communicate with each other through language. Be it expressing ideas or telling a story, language is an important social tool that we use to understand one another. Humans also have emotions. We can then express these emotions through language and various other means, such as body language or facial expressions. While the link between language and emotion is obvious, there is still a lot that we do not know about how they interact. There is a growing body of research dedicated to highlighting the important role that emotion plays in language processing. However, there are many areas that needs to be explored. My thesis aims to shed light on some of these areas to highlight how emotions can contribute to language processing. In this thesis, I used three well-established psycholinguistic methods to investigate the role that emotion plays in language processing. Using these paradigms, I conducted six experiments to understand the role of emotion in language comprehension, production, and prediction. The results obtained from these studies contribute to our understanding of these three major components of language use.

The most prominent theory in this thesis is grounded cognition theory. This theory holds that understanding a concept requires simulation of how that concept is experienced. This means that to understand the concept of kicking a ball, we can simulate the experience of kicking the ball without actually doing it. The second theory covered was the situation model theory. This theory holds that we construct a mental model in our minds when reading or understanding something. For example, when we read about lighting a candle using a match, we construct a model of that situation that may involve objects in that event (for example, matchsticks in the matchbox) and the sequence of actions that led to burning the wick on a candle. The third theory considered in this thesis was language prediction. This theory suggests that people use their prior experience and context to predict upcoming information when trying to understand a language. For example, when we hear “the crowd roars when the footballer kicked the ball into a…” we would predict what follows is “goal”. This simple prediction is thought to occur automatically, even when conversations are made with friends. However, these theories are often silent on how emotion is involved in each. Do we simulate being happy when we read about a character being happy? Do we consider a situation model that involves the emotional state of the character? And when and how do we use emotional information to predict upcoming information? These are the questions I will attempt to answer in this thesis.

Abstract

Emotions are an integral part of why and how we use language in everyday life. We communicate our concerns, express our woes, and share our joy through the use of non-verbal and verbal language. Yet there is a limited understanding of when and how emotional language is processed differently to neutral language, or of how emotional information facilitates or inhibits language processing. Indeed, various efforts have been made to bring back emotions into the discipline of psycholinguistics in the last decade. This can be seen in many interdisciplinary models focusing on the role played by emotion in each aspect of linguistic experience. In this thesis, I answer this call and pursue questions that remain unanswered in psycholinguistics regarding its interaction with emotion. The general trend that I am using to bring emotion into psycholinguistic research is straightforward. Where applicable and relevant, I use well-established tasks or paradigms to investigate the effects of emotional content in language processing. Hence, I focused on three main areas of language processing: comprehension, production and prediction.

The first experimental chapter includes a series of experiments utilising the Modality Switching Paradigm to investigate whether sentences describing emotional states are processed differently from sentences describing cognitive states. No switching effects were found consistently in my 3 experiments. My results suggest that these distinct classes of interoceptive concepts, such as ‘thinking’ or ‘being happy’, are not processed differently from each other, suggesting that people do not switch attention between different interoceptive systems when comprehending emotional or cognitive sentences. I discuss the implications for grounded cognition theory in the embodiment literature.

In my second experimental chapter, I used the Cumulative Semantic Interference Paradigm to investigate these two questions: (1) whether emotion concepts interfere with one another when repeatedly retrieved (emotion label objects), and (2) whether similar interference occurs for concrete objects that share similar valence association (emotion-laden objects). This could indicate that people use information such as valence and arousal to group objects in semantic memory. I found that interference occurs when people retrieve direct emotion labels repeatedly (e.g., “happy” and “sad”) but not when they retrieve the names of concrete objects that have

similar emotion connotations (e.g., “puppy” and “rainbow”). I discuss my findings in terms of the different types of information that support representation of abstract vs. concrete concepts.

In my final experimental chapter, I used the Visual World Paradigm to investigate whether the emotional state of an agent is used to inform predictions during sentence processing. I found that people do use the description of emotional state of an agent (e.g., “The boy is happy”) to predict the cause of that affective state during sentence processing (e.g., “because he was given an ice-cream”). A key result here is that people were more likely to fixate on the emotionally congruent objects (e.g., ice-cream) compared to incongruent objects (e.g., broccoli). This suggests that people rapidly and automatically inform predictions about upcoming sentence information based on the emotional state of the agent. I discuss our findings as a novel contribution to the Visual World literature.

I conducted a diverse set of experiments using a range of established psycholinguistic methods to investigate the roles of emotional information in language processing. I found clear results in the eye-tracking study but inconsistent effects in both switching and interference studies. I interpret these mixed findings in the following way: emotional content does not always have effects in language processing and that effect are most likely in tasks that explicitly require participants to simulate emotion states in some way. Regardless, not only was I successful in finding some novel results by extending previous tasks, but I was also able to show that this is an avenue that can be explored more to advance the affective psycholinguistic field**.**

Chapter 1: General Introduction

The past decade has demonstrated increasing interest of researchers in investigating the relationship between language and emotion. This is an important undertaking, as emotion permeates every aspect of our language, be it spoken, written, prosodic cues, discourse, and so on (Majid, 2012). In addition, interdisciplinary research is required to fully explore this link because both emotion and language are an inherent part of our culture (Jackson et al., 2019). These interdisciplinary forays involve various disciplines, including anthropology, linguistics, psycholinguistics, psychology, developmental and cognitive science, and computational and health sciences, are some of the efforts that have been put forward to further investigate how emotion and language interact (Lindquist, 2021). Affective science is in its nascent phase, and many questions remain to be answered. This thesis focuses on one aspect of this interdisciplinary effort, using psycholinguistic methods to investigate the role that emotion plays in three main aspects of language: language comprehension, production, and prediction. To do so, I investigated emotion using various emotional stimuli in key paradigms or tasks in each of these areas of language.

My focus on this chapter is first to elucidate what has transpired in the fields of emotion science, psychology, and psycholinguistics, and why more focus needs to be given to the emotional aspect of this field. It is important to note that this thesis does not attempt to provide aid or support for any of the models that I review; instead, I saw this as an opportunity to build upon this nascent area to contribute to a more general understanding of how these areas interact. For the sake of this thesis, I will focus only on three main aspects of language processing: language comprehension, production, and prediction. The literature and investigation in the science of emotion are vast, but there is no apparent consensus on it, and most accepted operational definitions need to be specific to the phenomenon of emotion that they investigate (Izard, 2010) or use catch-all operational definitions of emotions that encompass every aspect of emotional experiences (Gendron & Barret, 2009). For this thesis, I will focus on the conceptualisation of emotion in language and how it aids language processing (Adolphs, 2017).

1.1 **History of Psychology of emotion**

The study of emotion in psychology traces back its roots in multiple sources and mainly follows three fundamental traditions: basic, appraisal, and psychological constructionist. Basic emotion theories are generally predicated upon the combination of emotion and bodily response, much like the mind and body argument made by philosophers in the past (Robinson, 1976). Many reviews point to Darwin's publication of *The Expression of the Emotions in Man and Animals* (Darwin, 1872) as one of the first influential writings to argue that emotional expression, and thus emotion, is important for communication within species, and evolutionarily adaptive. Following that, William James posed a question in his seminal paper titled "What is emotion?" (James, 1884). In that essay, James argued that bodily changes are what is causing the emotions – later developed as James-Lange theory of emotions. James's work is highly influential and is among the most cited in the science of emotion. Cannon argued that both occur at the same time, as the processing of emotion does not occur before or after bodily activations due to its instantaneous nature (Cannon, 1927). These early writings are considered part of basic emotion theories (Gendron & Barrett, 2009).

The appraisal approach to emotion refers to meaning making when one experiences emotion. David Irons (1897) outlined the fundamental ideas of appraisal theories of emotions. Briefly, the ideas include the meaning analysis of the emotion being experienced, possible unconscious appraisal of the emotional experience, the relationship of the emotional objects and the self, discreteness to specific emotion, and partial participation of bodily changes for emotions to occur. The ideas of appraisal theories have been expanded by authors such as Dewey (1895) and, most notably, made popular by Arnold's (1960) emotion and personality volumes.

Another approach that is less discussed in the discourse of theorising emotion is the psychological constructionist approach. In a review by Gendron and Barrett (2009), this approach has its root with Herbert Spencer (1855), Wilhelm Wundt (1897) and even William James (1898). The idea of the psychological constructionist account of emotions refers to how emotions emerge from the basic psychical components. For example, upon seeing a tiger (context), a perceiver will have a stereotypical flight or fight mechanism, including increasing heartbeat and sweating (various physiological responses), from which the emotion of fear is derived. Therefore, emotion, referred to as experience by James, is an emergent property “occurring in the motor and sensory centres” (James, 1998, p. 473).

These approaches form the basis of the science of emotion in psychology and have evolved throughout the century. It still permeates in a lot of research that investigate emotion. For example, emotional expression has been used as a hallmark of many emotional studies, as it is easily observable which follows the traditions of cognitive psychology (e.g., Zajonc & McIntosh, 1992; Majid, 2012 for review). On another hand, research has also focused on using linguistic stimuli to investigate emotion processing in cognitive psychology. Examples include studies investigating the interaction between dimensions of emotions, such as valence and arousal, in various emotion word processing studies (for extensive reviews, see Citron, 2012; Kuperman et al., 2014), comparing emotional words and pictures (e.g., Bayer & Schacht, 2014), and the regulatory power of emotional language in emotional regulation and appraisal areas (e.g., Scott et al., 2019) and grounded models of emotion concepts in interoception (Connell et al., 2018; Critchley & Garfinkel, 2017; Lebois et al., 2020). Still, little is known about how emotions are used in language processing. Indeed, Izard (2010) gave a survey to prominent emotion researcher regarding the current outlook of emotional studies. The researchers participating in the survey agreed that the relationship between emotion and language had not been focused on. Regardless, the statement was made 10 years ago, and within this decade, there has been a lot of effort to understand the relationship between emotions and language. In fact, a recent integrative neurobiological model of emotion even includes the role that language plays in regulating and expressing emotion, even at the stage of pre-verbal feelings (Koelsch et al., 2015). Nonetheless, how emotional information affects language processing has not been well explored.

Why is this interface of language and emotion important, and why is it necessary to investigate it? The main reason could be that psychology have not focused on the role that emotions play. Various factors in the discipline may contribute to this lacuna. Some claim that theoretical interest in psycholinguistics naturally excludes any concerns about how emotion impacts language processing. For example, the tradition of psycholinguistics stems from generative linguistics (Chomsky, 1986) and compartmentalisation of language systems (Fodor, 1983). Furthermore, the notion that humans are passive processors derived from computational findings (e.g., Turing, 1950; Anderson, 1980) shifted the interest in psycholinguistic researchers to focus on emotion less or even none at all. These traditions cause theories and models to focus on modules that are specific to each linguistic level. These include phonological, lexical, and semantic modules (e.g., Carreiras et al., 2014; Coltheart et al., 2001; Hauk et al., 2006). Van Berkum (2018) also argued that the focus on psycholinguistic research that assumes people to be passive code crackers inadvertently rejects the involvement of emotion. Indeed, the split between language and emotion are not so rigid as it involves all aspect of linguistic experiences (Majid, 2012), including but not limited to, coded meaning (e.g., from word and sentence processing; see Hinojosa et al., 2019), pragmatics of meaning communication (Van Berkum, 2019) and social interaction (Jensen, 2014).

It is known that emotions and cognition interact (Damasio, 1994). Naturally, language and cognition also interact. One can view language as a medium for understanding emotions. The discussion of linguistic relativity (Whorf 1956) is outside the scope of this thesis, but if cognition is strongly associated with both language and emotion, what is the connection between them? Foolen (1997; 2012) proposed that language serves to conceptualise emotional concepts as well as a way to express specific emotions (although see Sauter 2018). This can be understood as the representation and expression of emotion concepts.

The question of interest is when and how emotion affect language processing. While the reverse can also be of importance, that is, how language affects emotion processing, the focus of this writing is to determine whether emotional content, if at all, aid in language processing. Research on emotions in the literature tends to focus on facial expressions, which is understandable given the amount of information that facial expressions can convey. For example, when people are angry, expressions such as frown and scowl are enough to indicate that we need to calm them down. Conversely, when we hear or read “Ali was happy when he won that contest”, how does the word happy contribute to language comprehension and/or production? Essentially, while we would have an expectation or representation of how Ali expresses his happiness (by either smiling or jumping from joy), how does this feature of emotion contribute to how we process the sentence? In short, how does the representations of emotion help or hinder language processing?

1.2 **Definition of emotion**

The definition of emotions has been debated, and its lack of consensus tends to make subsequent studies harder to conceptualise (Izard, 2010). The focus of this thesis is to examine how emotions impact language processing. It would be useful to properly define it to aid in developing a well-formulated research question. This yields a less semantically confusing term for emotion.

Emotion can be defined in various ways, even when there is still much disagreement regarding its conventional definition (Izard, 2010). Damasio (1999) focused on the role it plays at a neural level and on physiological changes. In fact, neurobiologists often describe emotions as a physiological change that occur in our body that our brain detects - leading to our recognition of it being a specific type of 'feeling' (Koelsch et al., 2015). For example, our body detects increased heart rate, gastrointestinal activities and sweating which is then associated by our brain to be the feeling of 'fear'. These changes in the autonomic nervous system (ANS) suggest that specific emotions would have a specific pattern of bodily activation, meaning that the automatic appraisal of changes in our body is due to a physiological change in our body. This is part of the classical view that emotions have distinct fingerprints or patterns in the ANS (Anderson & Adolphs, 2014; Ekman, 1984; Izard 1977). Regardless, the role of emotion to appraise, activate particular physiological reactions, and motivate discrete actions seems to be the common denominator for its functional properties in various emotional research and an important part of its definition (e.g., Frijda, 1986; Scherer, 2005; Barrett, 2014).

This reasoning for bodily changes can usually be seen in the language used to describe them. With the earlier example, the feelings of 'fear' could come into fruition when we know the meaning of 'fear'. The knowledge we know about our emotions allows us to make sense of the changes in our body. This line of argument, whereby language scaffolds our knowledge of emotion, follows the work of Barret (2006; 2017) which was part of the constructionist account of emotions. This means that while the instances of bodily changes in emotions could differ (i.e., ANS changes are not specific to a certain emotion); they can still be categorised as specific and discrete emotions. For example, both anger and fear could have mostly same biological markers as half of the physiological changes can be similar (Albert, 1953). However, they serve different functions based on what emotion the situation demands. Hence, whether you were angry or fearful depends on what kind of actions best fit the scenario - whether you need to reprimand someone due to anger or move away from the location due to fear.

Importantly, emotional language is not only restricted to express or label emotions but can also regulate it. Indeed, emotion words have been shown to be important in regulating emotions using affect-labelling. Wood et al. (2016) asked the question, why do emotion words exist in the first place if we only use non-verbal cues to perceive and comprehend emotions effectively? The author's reasoning is in favour of Lupyan's (2012) labelling hypothesis, which states that verbalisation of experiences enables categorisation of these experiences into something that we can infer from. They drew upon neuroimaging evidence (e.g., Lieberman et al., 2007) and results that showed different physiological responses when participants were asked to either report or ignore their emotional states after anger induction (e.g., Kassam and Mendes, 2013; see Lakoff, 2016 for review). Hence, the labelling of emotion can express, regulate and even change how we experience it, even at the basic physiological level. This functional property of emotion further outlines the strong connection between emotion and language processing.

1.3 **Why is emotion important in language?**

Under the Affective Language Comprehension model, Van Berkum (2018;2019) provided a well-elaborated account of the interaction between emotion and language comprehension. The key points are briefly discussed here. Following various prominent ideas in psycholinguistics (e.g., Levinson, 2006; Tomasello, 2008; Zwaan, 1999), the author argued that emotion holds in every aspect of linguistic processing models. For example, retrieving concepts during any utterance will activate traces of representation in long-term memory, including but not limited to the sensorimotor properties, and your affective experience with the concept. This is based on the grounded cognition (Barsalou, 2016). Furthermore, the author argues that emotion also appears in speakers' attempts to interpret the intended meanings of utterances and make inferences. For example, one might build appropriate situation models that reflect the receiver's world view, in order to infer speakers' referential intentions, stances, and social intentions (Johnson-Laird, 1983; Zwaan, 1999). Similar processes could occur when or reading about a character in a story. This process usually includes some aspects of affective concepts with differing intensities as a function of the context. The core assumption in this model is that emotion plays a role even when one refers to a seemingly neutral topic. To use the author's example; "The number 7 is a prime number" can also be emotional if it is said by a strict teacher, or if it was the only question you got wrong in the test you took long ago. An important take away from affective language comprehension model is that it combines insights from psychology, pragmatics, and emotion science and argues that emotion permeates all aspects of language comprehension. After all, the author argued that "rather than being orthogonal to it, emotion, in all its diversity, is central to cognition and action" (Van Berkum, 2018; pg. 652).

There is also a proposal that language is a necessary component to process and express emotions. For example, Barrett's and Lindquist's lines of work concern the way language scaffolds the conceptualisation of emotion (see Barrett, 2022 for a review). This means that language (words, sentences, discourse, utterance) is required to allow emotional concepts to be taught and understood. Without a marker to define complex physiological and psychological changes, one cannot understand or categorise emotions in ways that allow the organism to act functionally. The absence of language to conceptualise emotions can lead to an inability to understand one's own emotions and others, a condition labelled as alexithymia (Hogeveen & Grafman, 2021; Nemiah et al., 1976). Lindquist et al. (2015) angled their arguments from the perspective of developmental and cognitive psychology in their conceptual act theory. They posit that there is a distinction between sensation in our body due to feeling internal emotions (e.g., heart palpitations, increased skin conductance responses), external emotions (e.g., seeing a frown or a smile) and the conceptual knowledge of emotions. They concluded that the emotion words (happy, anger) are considered "essence placeholder" to attach meaning to these affective states. The language acquired when one acquires emotion words during development is used throughout adulthood (Lindquist & Barrett, 2012). Moreover, the observable experiences (e.g., a child associate anger with scowl and stern voices) are associated and build upon schemata that are learned and used as a guidance and prediction of future events. This argument extends the label-feedback hypothesis (Lupyan, 2012) that suggests linguistic and conceptual systems interacts to exert top-down forces during perception of an emotion. For example, associating and learning a constellation of behaviours (e.g., smile, yelling) with the label of ‘happy’ further create expectation of how happiness would be perceived in the future. Indeed, many studies have shown that labels can modulate behaviour (Lindquist et al., 2012, for review).

The models introduced above highlights the importance of emotion in language processing but also the interdisciplinary effort to truly understand this interface. The models agree that emotion presents itself from the earliest timepoint of processing until the later end of it. However, Van Berkum (2019) admits that there is not much empirical support to most of his claims. A recent review by Hinojosa et al. (2020) on the neural correlates underlying emotion at various levels of language processing further underscores that studies should consider the importance of emotional features in language processing. This is similar to how typical linguistic properties (e.g., word frequency and concreteness) are assumed to play an important role in determining how language stimuli are processed. The present thesis contributes to this effort by investigating how emotion words are processed in three commonly used psycholinguistic paradigms.

1.4 **Models of emotions**

1.4.1 **Discrete versus dimensional**

Irrespective of language, is there a universal pattern of behaviour that is shared across cultures? Are there discrete categories of emotions experienced by all walks of life? Based on Ekman (1992)’s seminal study, the basic set of emotions are disgust, anger, fear, happiness, sadness, and surprise. It is argued that these six emotions are universal and semantically distinct from one another (Bann & Bryson, 2014; Ekman, 1990). The participants in their study managed to identify and distinguish the facial expressions that were given to them. The research has been criticised as the methodology involves asking individuals to match emotional words to the posed, exaggerated facial expression that Ekman uses which can be unnatural and forced (see Jia et al., 2021 for review). However, the idea of six basic emotions has been influential in the study of emotions. Expansion of these initial six, or alterations, has been done throughout decades of scientific investigation.

Rather than distinct categories, an alternative approach considers emotions to vary continuously according to their shared properties. One influential theory is based on the degrees of valence and arousal. Russell (1980) proposed this model. This means that a discrete emotion is a unique combination of valence and arousal in two-dimensional space. Later, the model included more dimensions, although the strongest and most used remained valence and arousal (Kron et al., 2015). This dimensional rating has mostly been used in studies that involve language, as emotional stimuli such as words and pictures can be rated within these dimensions (Remington et al., 2000; Sutton et al., 2019). Here, the distinction between one emotion and another is blurred. For example, anger and fear can be both low-valence and high-arousal. The theories evolved and included more dimensions, such as dominance in the circumplex theory (2003), or even evolved to include more fine-grained differences of emotions in Plutchik’s wheel of emotions (1991; 2001). A study by Sutton, Herbert and Clark (2019) reviewed 7 databases of facial expression to identify the valence, arousal and dominance rating of these expressions. They found that positive (e.g., happy) and negative faces (e.g., angry) were strongly discriminated by valence. However, the negative facial expressions were not distinguishable by valence alone but needed both arousal and dominance dimensions to make them distinct.

Furthermore, an interesting analogy involve associating the dimensionality of emotion with that of colours. Hess (2017) outlined the similarities between emotional categories and colours. Each discrete colour is made up of biologically driven phenomena – the cone receptors that are responsible for coding of colours. However, colours also exist in the spectrum of wavelengths which are continuous. We do not identify redness with its biological underpinnings; we name it RED, and people understand what we mean when we say RED. The degree and intensity can differ, but we can clearly visualise what RED is. We also could not distinguish micro-changes in the colours. Similarly, when we say angry, we can visualise what an angry person would look like, but its intensity will be dependent on context. In short, colours vary in a continuous wavelength space, and we give different labels to different parts of that space. Similarly, emotions may vary in a continuous space with a two or more dimensions, with different emotion labels referring to different parts of the space.

Regardless, the important question is how people cognitively categorise and parse out all the details of their emotions. Do people represent emotions by having a discrete prototype of what each emotion should be, or are they placing emotions on a continuum and distinguishing them based on the location of the space within these dimensional theories? This remains a fundamental and unresolved question in emotion research.

1.4.2 **Emotion label and emotion-laden words**

Emotion-related concepts can be described in various ways, but recently a lot of focus has been on distinguishing between categories within the emotional domain in the mental lexicon. They can also be distinguished in two ways: either words that describe emotions themselves or words that describe concepts with emotional connotations (Pavlenko, 2008). These are referred to respectively as emotion label words such as *happy* and *sad*, and emotion-laden words such as *cemetery* and *birthday*. Emotion label words refer directly to expression of prototypical emotional states such as “being happy” and “feeling sad” (Clore et al., 1987). In contrast, emotion-laden words are said to be “words that do not refer to emotions directly but instead express or elicit emotions from interlocutors” (Pavlenko, 2008; pg. 148). Those words can include swear words, taboo words, aversive words, insults, and even interjections (e.g., ouch). Another important thing to note is how emotion-laden concepts are concepts that have emotional properties or can be rated on their degree of valence and arousal (Altarriba & Bauer, 2004; Lang & Bradley, 2007; Russell, 1980) and even sometimes dominance (Church et al., 1998; Fontaine et al., 2002). For example, a sub class of emotion-laden words are concrete words that have a specific degree of valence and arousal. For example, a *graveyard* would usually be rated as having low ratings in valence, implying that it is concept with negative connotation

(Kurdi et al., 2017). This suggests that representing object concepts can involve representing valence information.

Studies tend to mix these two types of words together in various affective behavioural tasks such as Emotion Stroop task (Ben-Haim et al., 2016; Williams, Mathews & MacLead, 1996), lexical decision tasks (Chen et al., 2015; Scott et al., 2014) and even affective Simon task (De Houwer et al., 2001; De Houwer et al., 2003). However, there are also studies that investigate the distinction between the two class of emotion words. For example, Zhang and colleagues report a clear distinction between these two classes of emotion words as they have different neural correlates (e.g., Zhang et al., 2017; Zhang et al., 2019; Wu et al., 2021). There is also a larger affective Simon Task effect for emotion label words compared to emotion-laden words (Altarriba & Basnight-Brown, 2011).

Altarriba and Basnight-Brown (2011) provided behavioural evidence to support the notion that emotional and neutral words are processed differently using bilingual evidence, focusing on the differences between emotion labels and emotion-laden words. They used an affective Simon task (De Houwer, 2003) with emotion words and neutral words in Spanish-English bilinguals. Here, they instruct the participants to focus on the valence (positive or negative) when words are presented in white ink or on the colour (blue or green hues) when the words are presented in colours. The result is interesting, as it not only shows that there is a difference in performance between monolinguals and bilinguals, but also between emotion label words and emotion-laden words. They interpreted their results in terms of valence and language dominance as factors contributing to these differences. As a result, this might slow people's reactions when negative concepts are presented, even when they are irrelevant to that task.

This is also the case in the emotional Stroop task, a variant of the Stroop task that includes coloured emotional words (Mckenna & Sharma, 2004). Regarding language dominance, they showed that the affective Simon effect is present in positive words in both languages, but only English showed the effect when presented with negatively valanced emotion words. They interpreted this as negative emotion words having a clearer effect compared to their emotional laden counterparts. The distinction between word type and associated processing is important, as previous studies usually intermix these two in their affective materials, even when they match lexical, valence, and arousal ratings (Basnight-Brown & Altarriba, 2018). They also argued that the emotion-laden word produced a 'mediated' effect rather than a direct effect. They suggest that emotion label words can have a stronger effect on linguistic processing, explain more variance in dimensional ratings like valence and arousal leading "to a 'purer' representation of emotion" (Basnight-Brown & Altarriba, 2018, pg. 417). Specifically, emotion label words have direct effects to language processing while emotion-laden have indirect and thus weaker effect on language processing. Taken together, this suggests that emotion labels and emotion-laden words are different and should be controlled for in studies investigating emotional processing in words.

1.5 **Affective valence and semantic valence.**

A distinction must be made in the study of emotions. What constitutes emotional response and what semantic knowledge of emotions? Simply put, what is the difference between feeling and knowing about emotions? A recent paper by Itkes and Kron (2018) call for an evaluation of how emotions are studied. They attempted to draw a line between stimuli that elicit certain emotional responses, termed affective valence, and knowing the degree to which an object/stimulus is considered to be negative or positive, called semantic valence. They argue that most studies can confuse the two. In their example, they referred to self-reporting affective experiences as a semantic evaluation of those affective experiences. This means that when we recall emotional events, we retrieve the semantics of the evaluation of those events. When we were tasked to recall our biggest achievement of the week, are we recalling our affective experience when we are achieving it, or just the knowledge or goodness of that particular memory? While the distinction can be pedantic, it is important to know whether simple recall would re-simulate happiness or pride when we achieved something.

A similar dichotomy has been drawn by other researchers. For example, taxonomies such as 'hot' and 'cold' emotions (Schaefer et al., 2003) or feeling versus cognitive appraisal (Roseman & Smith, 2001) suggest that experiencing emotions and knowing emotions may recruit different processes. For example, Niedenthal et al. (2009) performed a series of experiments to demonstrate that there are differences in processing these two types of distinctions: feeling and knowing emotions. Importantly, they note that context matters significantly. They looked at facial electromyography (EMG) while asking participants to generate emotional concepts that are either for a person they are really close to (termed 'hot' emotion features) or for someone they have working or formal relationships with (termed 'cold' emotions). The result is that while both participants can generate appropriate emotional concepts based on the two conditions, greater activation of facial muscles was detected in the production of 'hot' emotional concepts. This means that the embodied account of concept processing (discussed next) is supported by the findings, and that the context (task demands) can affect the outcome. In general, then, a distinction is often drawn between knowing about an emotion and re-activating the experience of having the emotion. Either could provide a basis for understanding emotions in language. However, the re-experiencing of emotions is a core tenet of embodied cognition theories, which I turn to next.

1.6 **Embodiment and Grounded Cognition**

A common underlying mechanism on how emotional information is being represented and can contribute to language processing can be understood from the perspective of grounded cognition. In this section, a brief historical review of grounded cognition will be discussed. Note that James thought of emotion as an emergent property that occurs "in the motor and sensory centres" (James, 1898, p. 473). Therefore, it is not a new idea but recently, a lot of empirical support from grounded embodiment studies has led to new proposal that emotional experience plays a key role in language.

Grounded or embodied cognition (also referred as 4E Cognition: Embodied, Embedded, Enactive, Extended) loosely refers to the activation of multimodal traces upon comprehending or encountering particular concepts (Barsalou, 1999; 2008; 2016; Newen et al., 2018). A concept is defined as a mental representation or knowledge of a particular information or phenomenon in its most atomic form (Payne et al., 2007). It is interchangeable with lexical (word) meaning, as is usually used in studies that use linguistic stimuli (Margolis and Laurence, 1999). In grounded cognition, concepts are generally understood to be grounded in concrete and sensorimotor modalities used to experience them. This is in stark contrast to the view that cognition is modular and independent from the action used to enact it (Fodor, 1975). Even recently, Barsalou (2020) presented the Situated Action Cycle that includes the “relations between perception, cognition, action, and other relevant domains, including the environment, affect, and outcomes” (pg. 3).

Grounded cognition from its inception (Barsalou, 1999), has been under rigorous scientific debate over the past two decades (Goldinger et al., 2016; Mahon & Caramazza, 2008). Burgeoning empirical research supports grounded cognition, including but not limited to neuroimaging, behavioural, and computational methods (e.g., Pulvermuller et al., 2005; 2013; Coello & Fischer, 2016; Binder et al, 2009; see Barsalou 2020 for review). The general idea of this research is that the sensorimotor areas become activated after comprehending relevant concepts but without enacting the actions. Theorists supporting this embodied cognition range in their interpretation of the involvement of the sensorimotor areas. A spectrum of embodiment theories has been identified (Meteyard et al., 2012). At one end, semantic representation is thought to be heavily dependent on sensorimotor regions (strong embodiment, e.g., Gallese & Lakoff, 2005), and the other extreme it is a purely symbolic conceptual representation (symbolic theories; Collins & Loftus, 1975; Levelt, 1989). For example, when we access a particular concept, we simulate the sensorimotor experiences associated with it by re-activating the brain regions involved. For example, when we hear the word “kick” we simulate the experience of kicking by reactivating parts of the motor cortex involved in this action. Grounded cognition theories hold that these simulations are an important part of understanding language – how important depends on how strong or weak the theory is. Nonetheless, within this spectrum of theories, a combination of symbolic and sensorimotor representations is what garners the most empirical support. This includes a combination of amodal and modality-specific regions interacting separately (secondary embodiment: e.g., Mahon & Caramazza, 2008) to semantic information being coded in regions proximal to those that support the experiences they relate to (weak embodiment; e.g., Barsalou 1999; Vigliocco et al. 2004).

Regardless of the stances that different researchers have on grounded cognition in the spectrum identified by Meteyard et al. (2012), there is converging evidence that grounded cognition underlies our cognition (Barsalou, 2020; Galetzka, 2017). Some theorists have even suggested that this could be a paradigm shift in psychology, which has been debated by embodied critiques (e.g., Goldinger et al., 2016, cf. Barsalou, 2016). This shows the influence of this theory in the field of cognitive neuroscience, especially in semantic memory (Davis & Yee, 2021). Henceforth, borrowing the terminology, I will refer to this theory as either embodied or grounded cognition for the remainder of this thesis. Though the word embodied suggests that cognition only requires the physical body, empirical research has shown that it includes beyond that, such as social and physical environments in which the person is embedded (Kessler & Thomson, 2010). While early work focused on the role of sensory and motor simulations, there is now increasing interest in how interoceptive experiences might support understanding of more abstract concepts, such as those involving emotion.

1.6.1 **Abstract vs. concrete**

In his dual-coding theory, Pavio (1990;1986) identified and divided concepts into two categories. According to this theory, semantic memory has two systems that are associated with verbal and nonverbal memory. Verbal systems use language as a medium to process information, whereas non-verbal systems deal with phenomena that are usually perceivable (i.e., experiential). Specifically, linguistic systems are associated with processing concrete and abstract concepts (including emotion label concepts), whereas non-verbal systems are more associated with experiential and concrete concepts. Current research tends to view this division of concepts as concrete and abstract concepts (Mkrtychian et al., 2019). Much research under the banner of grounded cognition has been conducted on concrete concepts because of its empirical and theoretical feasibility (Bersalou 2018). This is because sensorimotor experiences are more associated with things that can be experienced, acted, and perceived (e.g., cats, chairs, tables, planes).

Embodied cognition has a fair share of criticism throughout its development. The most relevant aspect of this thesis is the grounding of abstract concepts. The evidence described above focuses mainly on investigating concrete concepts (e.g., Pulvermuller et al., 2005; see Kemmerer, 2019 for review), but abstract concepts present challenges to embodied cognition theories (Barsalou, 2020). Concrete concepts (e.g., chairs and balls) have direct referents in a world where one can observe or interact with them. Therefore, observing a concrete object and thinking about the concept of a chair activates the constellation of multimodal traces of your previous experiences with the chair, such as seeing and sitting on it.

Various studies have shown that sensorimotor systems are important for the organisation of concrete objects. For example, Farah and McClelland (1991) provided a parallel distributed processing model of semantic memory for living and non-living things. In a series of experiments, they found that when visual semantic units were damaged, impairments in knowledge of living things were observed. Conversely, impairments in the processing of non-living things were observed when functional semantic units were lesioned. They argued that sensory information is important for identifying living things, while the functional properties of an object are more important for non-living objects (for review, see Humphreys & Forde, 2001). In another study, Dilkina and Lambon Ralph (2013) used a data-driven approach to investigate the conceptual structures of object knowledge in four feature types: perceptual, functional, encyclopaedic, and verbal. They found that items from the same category tended to share features of all four types. However, perceptual features best predicted general taxonomic categories, highlighting the role of perceptual similarity in categorising objects, mostly in the concrete category. These studies highlight that concrete objects are grounded in sensorimotor systems, more so than abstract concepts.

As abstract concepts do not appear to depend on sensorimotor experience, researchers have sought other aspects of experience that may be important to understand them. Connell et al. (2018) asked participants to rate 32 000 concepts on the degree to which they were experienced in the five sensory senses. The novel finding of this mega study is that they included another sensory system which is interoception. Interoception is defined as sensations that occurs within an individual’s body including autonomic (e.g., hunger, tired), cognitions (e.g., think, belief), and emotions (e.g., happy, fear). They found that interoceptive strength explain comparable or even more variance than the other five senses in abstract concepts (compared to concrete concepts). Testing only emotional concepts, they also found that interoceptive strength is associated more with emotion concepts than with other concepts of similar abstractness and valence ratings. They concluded that emotional concepts are grounded in interoception rather than in perceptual systems. The implication of this interpretation is that abstract concepts use affective information to ground them into the appropriate experiential system (Critchley & Garfinkel, 2017 for a similar argument). Therefore, emotional properties are important components of abstract concepts. Winter (2020) demonstrated that concrete objects can also be associated with high valence and arousal ratings, suggesting that people activate affective components to represent concrete objects. This might provide evidence that interoception can be a source for grounding of concrete concepts. Since much research on affective and social grounding has been dedicated to abstract concepts (Reinboth & Farkas, 2022), less is known about how concrete objects may activate regions beyond the sensorimotor systems.

Alternatively, abstract concepts could also be grounded in a language system (Glenberg & Gallese, 2012). This is seen in theories such as conceptual act theory (Barrett, 2006; 2009; Wilson-Madenhall, 2011). This theory posits that experiences derived from our environment (e.g., socialisation and cultural artefacts) become "real when they are categorised as such using emotion concepts knowledge within a perceiver" (Barrett, 2014; pg. 293). A recent extension of this theory can be seen in words as social tools theory (Borghi et al., 2020), where it also postulates that abstract words are shaped not only by sensorimotor systems (specifically the mouth motor system), but also the social and linguistic system obtained through experience. Additionally, the authors noted the importance of systems such as interoception (e.g., emotion and inner states) and social, linguistic, and metacognition in grounding abstract concepts. These theories seem to suggest that interoception and language are important components that need to be considered when dealing with the embodiment of abstract concepts in general and emotion concepts in particular. With the example of observing the chair earlier, this can include properties beyond sensorimotor experiences, such as individuals' personal experiences with the chair, including emotional attachment and the social function of the chair.

Abstract concepts that have recently received attention include emotion. Winkielman et al., (2018) posits that emotional concepts are both abstract when they involve interpersonal and social relation with others (i.e., schemata of what a good person is) and concrete due to their ability to involve interoceptive and bodily changes. Additionally, emotion concepts can refer to sensorimotor and bodily changes (i.e., interoception). Therefore, the degree of flexibility of emotion garners much interest from grounded theorists (Myachykov & Fischer, 2019). Supporting this, in a distributional semantic analysis, abstract words have been shown to co-occur in contexts with high emotive value which may result in previous findings that abstract words contain more affective information than concrete words (Lenci et al., 2018). Some even suggest that emotion is another type of concept, in addition to concrete and abstract concepts (e.g., Altarriba and Bauer, 2004; but see Mkrtychian et al., 2019). Importantly, an influential view is that abstract concepts can be grounded in affective systems which is usually referred to as affective grounding hypothesis (Kousta et al., 2011; Vigliocco et al., 2009).

Other behavioural evidence has also shown links between action and emotional language processing (Lindquist & Gendron, 2013 for review). In a seminal behavioural study, Havas et al. (2007) asked participants to read short pleasant or unpleasant sentences while holding a pen using their teeth (simulating smiling) or lips (disabled smiling). They found faster reading times when participants read pleasant sentences while smiling compared to when they were not smiling and vice versa. Studies utilising facial electromyography (EMG) have found a strong link between facial muscles involved in the act of frowning (corrugator supercilia) or smiling (zygomaticus major) impacted by the content that they read. This is under the main assumption that simply perceiving smiling or frowning elicits automatic and unconscious activation of the perceiver's facial muscles (e.g., Dimberg et al, 2000). Various other facial EMG have been used to demonstrate that this effect is present in different linguistic classes, such as emotional action (to smile) and state verbs (he enjoys) (Foroni & Semin, 2009; 2011; Fino et al., 2016), in morally loaded narratives and evaluations ('t Hart et al., 2018), but only when the semantic content (compared to perceptual content) of the emotional words is accessed (Niendenthal et al., 2009). Moreover, this evidence was extended, such that when botox was injected to temporarily prevent any facial movements (especially frowning), the same pattern emerged (Havas et al., 2010). This line of study has been used as evidence of emotional expression that contributes to language comprehension, especially in the realm of social interaction and motivations such as facial mimicry (e.g., Hess & Fischer, 2014), and extends beyond emotional words as well as narratives. However, a passive reading task of implied emotional sentences (e.g., the boy fell asleep and never woke up again) did not activate any motor regions. Instead, various other language processing areas were instead activated compared to neutral sentences (Lai, et al, 2015). Taken together, the simulation of facial expressions might lead to embodiment of emotions in action and motor systems.

In summary, abstract concepts (including emotional concepts) have traditionally posed a challenge to embodied cognition theories as they have not been thought to depend on sensorimotor experience. More recent research has identified a number of ways in which they might be linked to bodily experience: through simulation of interoceptive experiences like emotional states, through simulation of emotional acts like smiling and frowning, as well as through representation in the language system. It has also been argued that emotion concepts are grounded in sensorimotor and interoceptive systems in a dynamic way as they recruit and reinstate the necessary neural networks as a function of the context (Winkielman et al, 2018).

1.6.2 **Automaticity of emotion**

Embodied cognition theories claim that simulation of emotional states can support our understanding of language, particularly for more abstract concepts. This view assumes that emotional experiences are rapidly and automatically activated. The Affective Primacy Hypothesis can also support this notion of prioritised emotional processing compared to other types of processing. In the first inception of the Affective Primacy Hypothesis, Zajonc (1980) argued that affective reactions are quick and automatic compared to non-affective processing, such that they will always take priority before determining its ontological properties. This is usually in contention with the Cognitive Primacy Hypothesis, which suggests that people process the categorical nature of a stimulus before evaluating (consciously or unconsciously) its affective properties (Lazarus, 1984; Storbeck et al., 2006). However, recent literature strongly suggests that people activate either the affective or ontological properties of the stimulus as a function of the context of the stimulus (Lai, Hagoort & Casasanto, 2012).

Studies that support the automatic view usually claim that processing emotional words tends to activate emotional areas (e.g., amygdala, insula, orbitofrontal cortex) prior to the usual time that semantic representation is usually processed, usually around 400 ms after the onset of words (Grainger & Holcomb, 2009; Kutas & Federmeier, 2011). Ponz et al. (2014) provide evidence to this claim. In their study, they combined EEG and intracranial EEG and found that the insula (associated with disgust) activation was approximately 200 ms post stimulus. The interpretation of this finding is that the brain automatically processes emotionally salient objects and written words. This is in line with the grounded theories of grounded cognition (see Majid, 2012 for review).

There is also ample evidence that emotional words have different properties than neutral words. It has been shown that people are slower to respond to negative words than to positive words in lexical decision tasks (Estes & Verges, 2008; Estes & Adelman, 2008), emotional Stroop tasks (e.g., Williams et al., 1996; Ben-Haim et al., 2016), and word naming (Algom et al., 2004). Trauer, Kotz & Muller (2015) asked participants to perform lexical decision tasks. They compared emotional words (e.g., torture) to neutral words (e.g., profession) and pseudowords. They found that negative emotion words facilitated the P200 (indicating early lexical access) and N400 (associated with difficulty in semantic processing) components compared to neutral words. These ERP components were said to index the preferential processing of emotional words, as it occurred during early processing. They argued that emotional words were facilitated more easily and received priority in lexical access. For example, emotional words are shown to be retrieved faster than neutral words (Kissler & Herbert, 2012). This facilitatory effect was replicated to varying degrees (e.g., Katske, & Kotz, 2007; Schacht & Sommer, 2009; Ashley & Swick, 2009; Mathewson, Arnell, & Mansfield, 2018; Altarriba & Bauer, 2004; Carretie, 2014 for review), even though the components tend to differ in amplitude because of task-specific effects (Citron, 2012). Facilitation of processing due to emotional words mirrored the findings in emotional pictures, where arguments were made towards the attention-grabbing nature of emotional stimuli (Herbert, 2020; Hinajosa, Moreno, & Ferre, 2019; Innes-Ker & Niedenthal, 2002; Junghofer et al., 2001). Taken together, there is a wealth of evidence that emotional concepts are processed differently from neutral concepts.

These studies have highlighted that emotional words, usually in the form of emotion-laden words (e.g., funeral), are processed differently than neutral words. This is usually supported by affective versions of well-established psychological tasks created to further understand how emotions are processed. An example that is worth mentioning is the Affective Stroop task, as it shows the automatic processing of emotional information and also rivals that task that it is based on (for reviews, see Bar-

Haim et al., 2007; Williams et al., 1996). The emotional Stroop effect is the finding of longer naming latencies in naming the colour of the font of emotional words compared with neutral words. The authors using this task reasoned that emotional words have preferential and automatic processing compared with neutral words (Holle, Neely & Heimberg, 1997; Ben-Haim et al., 2016).

There are increasing amount of evidence that emotion modulates attention (Phelps et al., 2006; Ohman et al., 2001; Oliveira et al., 2013) which can be derived from the motivational attention model of emotion (Lang et al., 1990). This model holds that emotional stimuli grabs more attention than neutral stimuli (Lang et al., 1997). Concerning valenced words, both negative and positive words were responded similarly faster than neutral words, causing an inverted U-shaped response time against the valence ratings of words (Kousta, et al, 2009; Vinson, et al, 2013; Kanske & Kotz, 2007). Additionally, Crossfield and Damian (2021) found that only positively valenced words are processed faster than negative words, which in turn is faster than neutral words in lexical decision task. They argued that only positively valenced words were confidently shown to facilitate processing while negative words tend to be modulated by other variables. Conversely, in a study that utilised a bigger corpus of words (around 12 000), Kuperman et al. (2014) identified that once all lexical and semantic variables are controlled for, emotion-laden words have the following properties in lexical decision tasks: (a) positively valence words are processed faster than neutral words, and neutral words are processed faster than negatively valenced words, and (b) highly arousing words (e.g., sex) are processed faster than less arousing words (e.g., meditate). These conflicting findings can be reasoned to be the result of possible confounds from lexical and sublexical variables (e.g., contextual diversity) in the stimuli used in these various studies (Crossfield & Damian, 2021). Regardless, these findings echo that positively valenced words are highly influential in word processing.

There are also studies that suggest that emotional information has prolonged processing compared with neutral concepts. For example, Yamada and Kawabe (2011) suggested that participants perceived or overestimated the time they spent viewing negative valence images compared to positive or neutral images, even when the task was not relevant to processing emotion (Yamada & Kawabe, 2011; Kobayashi & Ichikawa, 2016). This suggests that negatively valenced images captured attention based on both valences. Additionally, Gernsbacher, et al., (1998) measured reading times when participants read sentences that either matched or did not match the emotional content in the preceding short narrative. The typical finding is that people are faster to read target sentences after a narrative that has matching emotional content compared to mismatching emotional content (called the mismatching effect; Gernsbacher et al., 1992). They also asked participants to perform a concurrent task (e.g., memorising a random consonant during reading) to investigate the effect it had on the mismatching effect. They found that the mismatching effect was similar to that when there was no concurrent task. They concluded that emotional inferences are automatic and effortless. Paulmann and Kotz (2008) asked participants to hear emotional and neutral speeches while doing a probe verification task. They found that people were able to distinguish emotional speech from neutral speech as early as 200 ms, based on their ERP data. They argued that this could be because emotional processing was quickly attended as it involved different neural pathways from the primary cortex (cf. Liebenthal, Silbersweig, & Stern 2016 for review).

Furthermore, Imbir et al. (2020) showed that not only the meaning of emotional words but also the visual attributes of emotional words were automatically processed using a modified flanker task. Here, participants needed to identify the colour of emotionally loaded target words (e.g., the word *kill* written in green font) when it is being surrounded by distractors in the congruent conditions (e.g., the word '*green'* with green font) versus the incongruent condition (e.g., the word *red* written in red font). It was found that people were slower in incongruent conditions than in congruent ones. This suggests that people processed the visual properties of emotionally loaded words even when the task was not relevant to processing emotions, suggesting automated visual and semantic processing of emotion words.

Several studies cautioned comparing the results of different tasks, as emotion effects were dependent on the task. Crossfield and Damian (2021) asked participants to perform Lexical Decision task (LDT) and Emotional Stroop task (EST). They found that positively valenced words only facilitated the processing of words in lexical decision tasks, but valence itself did not modulate the reaction time in the Emotional Stroop task. They argued that valenced words automatically activate more semantic information and, hence, are quicker (semantic richness argument). Indeed, valence has also been shown to have a greater effect on lexical decisions than naming responses (Kuperman et al., 2014). Additionally, Delaney-Busch, Wilkie, and Kuperberg (2016) showed that the impacts of valence and arousal differ as a function of task demand. In their study, valence modulated the late positivity potentials (LPC) which are associated with prolonged processing of emotion (compared to neutral) words in a valence categorisation task. At the same time, in a simple categorisation task (where participants had to decide whether the word is an animal or something else), arousal was the dimension that modulates the LPC but not valence.

In conclusion, there is ample evidence that emotion is automatically activated and impacts language processing in range of settings. It is possible to argue that emotional words are processed differently from non-emotional words. Since Zajonc (1980) argued for the processing primacy of emotional stimuli, many other studies have replicated this result (but see Storbeck et al., 2006). However, one could also argue that these effects could also be task specific. Therefore, it is important to study the effect of emotional content in a range of different language processing tasks, to determine how and when emotional associations become activated and influence processing. This is the aim of this thesis. Before reviewing the specific psycholinguistic methods used in the thesis, it is necessary to consider one other aspect of language processing in which emotions might play a critical role: in the construction of situation models.

1.7 **Situation Model**

The situation model is another prominent conceptualisation that proposes a role for emotions in language processing. The situation model is defined as a mental representation of an event (Zwann, 1999). Rather than specific representations of isolated words, sentences, or clauses, situation models are usually used in discourse (e.g., novel, news), whereby mental representations of agents, events, goals, plans, etc. are constructed. The situation model constructs the current event during text or discourse comprehension and uses prior experience or memory to form a coherent representation of the event being described.

Various studies have shown that people also include emotional information when constructing situation models. Gernsbacher, Goldsmith and Robertson (1992) asked participants to view short narratives that implied specific emotions followed by either a sentence that matched the emotional content of the previous sentences (matched condition) or the opposite (mismatched condition). Using a self-reading pacing task, they found that people were slower in the mismatched category than in the matched category. They interpreted this as the participants constructing a coherent situation model that included the emotional state of the character throughout the text. Further variation of this mismatching effect informs us that the situation model extends beyond the local text (deVega, et al., 1996), is specific to the knowledge of the main character in the text (de Vega, et al., 1997), is present even under cognitive pressure (Gernsbacher, et al, 1998), perspective (first person vs. third person) (Gillioz et al., 2012), and can be dependent on the expertise of an individual (Gygax et al., 2008). The exact information used to construct the situation model is unclear, that is, whether the emotion being constructed is a specific emotion (e.g., Gernsbacher et al., 1992) or more a general representation of textual valence (Gygax et al., 2004). However, the degree to which people incorporate detailed emotional information into their situation model depends on the amount of context available to infer this information (Gillioz & Gygax, 2017). Even with this amount of evidence, there is still no clear explanation and mixed results regarding what and how they use emotional information to construct these complex situation models (Gygax and Gillioz, 2015).

The situation model can also be related to the embodied perspective in explaining abstract concepts, including emotional information. For example, t' Hart et al. (2019) found that facial muscles remain stable across inconsistent fair-based narratives. In this study, participants were asked to read a narrative that included a moral or immoral character which either received a good outcome (fair or unfair, respectively) or a bad outcome (unfair or fair, respectively), while their facial muscles were observed using EMG. They replicated the typical finding of congruent language-muscle activation (negative concepts induce frowning and vice versa). Importantly, the facial muscles appeared to be consistent from the first encounter of the emotional words (e.g., John is happy to donate to charity) until the affective resolution (e.g., "He won the grand prize" in the fair if the character deserved that karma). They took the results as the participants created and maintained an active representation of the situation model. Whether this is the result of embodying specific lexical items in the text or discourse is unclear.

Zwaan (2016) argues that the content of situation models can include sensorimotor simulations and more symbolic representations, depending on the context and experience of the comprehender. Taylor and Zwaan (2009) gave an analogy of a person understanding the event of a high jumper performing their sport. For people who have not observed or experienced the sport (or even lack contextual understanding or vocabulary), they will not know what the 'bar' in the situation represents. Instead, a symbolic representation of a person jumping over something will be generated. For people with experience, more sensorimotor activation will be activated simply because they have performed the movement before. They can also understand more of the situation (e.g., the risk, satisfaction) of performing the events, leading to a deeper understanding of the situation being communicated (Chow et al., 2015; Holt & Beilock, 2006 for evidence). This theoretical stance can explain the notion of "I can feel the pain" when we witness injuries that are very relevant to ourselves.

Likewise, processing emotion can also be similar, in that, as we build a mental representation of the event of someone's getting angry, we may use both symbolic and experiential (sensorimotor or interoceptive) processing to attempt to understand it. Our experience of the event then will dictate the extent of the involvement of these two processes. In line with this dual-process view, neuroimaging evidence has found that emotion sentences activate key areas implicated in emotional processing, such as the amygdala (e.g., Adolph, Russell, & Tranel, 1999), as well as various other language-driven networks, including regions associated with combinatorial tasks in sentence processing, the inferior frontal gyrus (Menenti et al., 2009), and regions associated with inferential processing, such as the medial prefrontal cortex (Ferstl, 2010). The same robust activations can also be seen in sentences only implying emotions, for example, "the boy fell asleep and never woke up again" (Lai, Willems, & Hagoort, 2015) compared to sentences that include words that have emotional connotations (Moll et al., 2002; Adolphs et al., 1999). Furthermore, it has been shown recently that person's emotional state (such as moods) affects attention, semantic and syntactic processing (Chwilla, 2022).

To summarise, there is strong evidence that people consider emotional information in processing language, even to a degree of representation of the agent's emotional state during a sentence or discourse representation. Indeed, Zwaan (2016) further proposed that prediction can be a useful mechanism that contributes to the construction of situation models. Indeed, understanding the emotional state of the people described could help us anticipate upcoming events or actions and better understand the situation involved. We likely do this by mentally simulating the agent's motivations and goals during comprehension (Zwaan, 1999) which could also include their emotional states (Gernsbacher et al., 1992).

1.8 **Psycholinguistic methods used in this thesis.**

So far, my review has highlighted many areas of psycholinguistic studies that have addressed how emotion information impacts language processing. Many psycholinguistic paradigms have been used mainly with concrete, non-emotional concepts. Where emotional content has been studied, effects have sometimes been found to be variable and task dependent. Therefore, I aimed to extend the literature by using established psycholinguistic tasks to investigate the link between emotion and language processing. I considered three paradigms: the Modality switching paradigm, Cumulative Semantic interference paradigm, and Visual world paradigm. These paradigms are used to investigate language comprehension, production, and prediction respectively. In the next section, I briefly review and link these paradigms with the outstanding questions identified in the above literature review. A detailed discussion and the motivation for each experiment are provided in each chapter.

In brief, **Chapter 2** used the modality-switching paradigm to investigate the role of emotional experience in sentence comprehension. Embodied cognition theories predict that emotional sentences involve simulation of emotional states and are therefore processed differently to non-emotional sentences. I investigated whether people experience a processing cost when they switch between understanding sentences that describe emotional experiences and those that describe non-emotional cognitive experiences. **Chapter 3** used the Cumulative Semantic paradigm to investigate whether valence is an important organising principle in representing and thus categorising concrete objects. Based on various theories that I reviewed, it is likely that valence can be used to categorise and represent concrete objects, especially when they have inherent valence properties. **Chapter 4** used the Visual world paradigm to investigate whether emotional state of an agent is used to predict the incoming information regarding the cause of the that state. Previous research suggests that people are capable of inferring the emotion of an agent in a text, but not how they will use it predictively.

1.8.1 **Modality switching paradigm.**

In theories of embodiment, the comprehension of concepts is linked to associated sensorimotor processing. Evidence supporting this is mostly from neuroimaging, which shows activation of modality -specific processing regions upon concept comprehension (Meteyard et al., 2012). However, behavioural studies have also sought evidence for modality-specific processes during comprehension.

Behavioural studies that support the theory of embodiment often utilise the Modality Switching paradigm (Pecher et al., 2003). In this task, participants had to process the meaning of a concept in a property verification task (e.g., verifying whether an apple could be red), and their reaction time was recorded. Importantly, they had to verify the properties of concepts from different perceptual modalities (e.g., “An airplane can be loud” for auditory modality; ‘Grass can be green’ for visual). Trials that probe the same perceptual modality as previous trial (same condition) are generally faster compared to trials where the probed modality is different to the previous trial (switch condition). The authors interpreted this finding as people switching their attention when they processed concepts embodied in different perceptual modalities, an effect called the switch cost (or modality-switching effect). This effect suggests that processing concepts relies on sensorimotor activations as there is an attentional cost or lag when the concepts switch in perceptual modalities. Therefore, amodal symbolic presentation cannot explain this pattern of data (van Dantzig et al., 2008). One study utilising these tasks replicate and found that the switch cost effect is also present when the modes of stimuli’s presentation was manipulated (e.g., half of the stimuli is presented auditorily or written; Scerrati et al., 2015) suggesting that people simulate the relevant modalities when reading and when listening. Scerrati et al. (2017) also suggests that if the task was a lexical decision task which denote shallower processing, switch-cost are not found. Therefore, when a deeper processing is required, the switch cost is present.

A similar switch cost effect has been found when people switch between perceptual and affective semantic processing. Vermeulen et al. (2007) asked participants to verify the perceptual properties as in previous studies, but they also included affective properties of different valence (e.g., “Victims can be stricken” and “Laughter can be heard”). They found the same switch cost effect when people changed between verifying the perceptual and affective modalities. Oosterwijk et al. (2012) also found a switch cost effect between sentences describing interospective mental states from an internal and external focus. They found that people were slower to verify sentences describing internal (e.g., “He is saddened by the exam result”) followed by external focus (e.g., “His tears flowed during the funeral”) to sentences from the same focus (e.g., “She is felt calm and collected during meditation”). This suggests that people simulate introspective states differently when they focus on their internally-experienced versus externally-observed aspects.

Indeed, reenactment of emotional states can facilitate emotional sentence comprehension. For example, Glenberg et al. (2009) highlighted that congruence between emotional states and comprehension of emotional sentences facilitates sentence comprehension. They argued that reading emotional sentences simulated concurrent emotional states. Hence, when one switched to comprehending sentences that described other emotional states, people were slower than when they had to comprehend sentences that described a similar emotional state. This switching effect enabled us to understand how emotional concepts were embodied. Therefore, a question of interest here is whether there can be any differences between processing emotional concepts and non-emotional concepts.

Previous studies have found that there is a processing cost when people switch between semantic processing relating to different perceptual modalities, or when they switch between perceptual and affective modalities. There is also a cost when switching between understanding mental states from the perspective of the experiencer or an external observer. However, if comprehension of emotional content involves re-enactment of emotional states, then emotion should form a distinct “modality” which is processed differently from non-emotional states (e.g., cognitive states such as forgetfulness). This has not been tested previously. Therefore, in **Chapter 2**, I will address the question of whether emotional concepts have a different modality from other concepts in introspective categories using this paradigm. In short, I am interested in whether interoceptive states, which I defined as emotional or cognitive, are processed differently.

1.8.2 **Cumulative Semantic Interference**

As reviewed earlier in this chapter, our semantic systems for representing concrete objects are thought to have strong category-based and perceptual organisation, while abstract concepts utilise more linguistic or emotional grounding. Recent findings suggest that the divide is not very accurate (Winter, 2022) and most investigations of emotional concepts have been conducted on emotion-laden objects. Therefore, I sought to investigate the role of emotional information in categorising emotion label concepts (e.g., happy, sad) and concrete objects with emotional connotations (i.e., emotion-laden objects). Using the Cumulative Semantic Interference (CSI) paradigm, I investigated the extent to which affective information (e.g., valence, arousal) contributes to the semantic representation of emotion-laden objects. To this date, there is no study that investigates emotional categorisation using CSI or whether objects that are similar in affective dimensions like valence interfere with one another in semantic access tasks.

CSI refers to the slowing in response times in semantic tasks (typically picture naming) when a number of semantically related items are presented in close proximity (Belke et al., 2005; Damian et al., 2001; Howard et al., 2006). Though there are a number of theoretical models of the effect, it is generally thought to be caused by the build-up of interference between lexical-semantic competitors. Before it was known as CSI, many studies have investigated how and why interference occurs during picture naming. There is ample evidence that lexical retrieval during picture naming is semantic in nature (e.g., Dell et al., 1997; Glaser, 1992) and is a competitive process (e.g., Levelt et al., 1999; Roelofs, 1992). For example, the time taken to name pictures is longer when they are structurally similar (versus structurally dissimilar items) and also more errors are produced under time constraints (Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1993). Unlike priming effects in most psycholinguistic studies (e.g., McDonough et al, 2013; Grey & Tagarelli, 2018), in naming tasks, the presentation of semantically related items interferes with the soon-to-be target words (Belke et al., 2005; Oppenheim et al., 2007). There is evidence that the interference occurs at the semantic level instead of visual, or at the lexico-semantic locus. For example, the CSI effect is present when the ratings of visual similarities are controlled (Vigliocco et al., 2004) and disappear in word naming tasks that do not require semantic access (Damian et al. 2001). Therefore, there is strong support suggesting that the interference occurs at the semantic level.

Semantic interference is also present when a context of the pictures' appearances is manipulated (e.g., Belke & Stielow, 2013). For example, target pictures are named more slowly when they are named in a block full of semantically similar images (homogenous or related block) compared to semantically dissimilar images (heterogeneous or unrelated block). A CSI effect is observed when related blocks (with more items that are within the same semantic categories) have slower reaction times than unrelated blocks (with mixed items from different semantic categories). For example, a related list of animals (DOG, CAT, GOAT) will have a slower average reaction time in a naming task than a list of unrelated items (DOG, TRAIN, TRUMPET). The slowing is present whether each picture is named once or multiple times (e.g., Brown, 1981; Kroll & Stewart, 1994; Maess et al., 2002).

Extending this further, a variant of this blocked naming called the blocked-cyclic presentation of pictures involves repetition of the same items within blocks. This presentation method has been frequently used to induce CSI effects in patients with aphasia (Belke et al., 2005; Schnur et al., 2006; McCarthy & Kartsounis, 2000) but is also commonly used to investigate interference in healthy populations (Crowther & Martin, 2014; Damian et al., 2001; Feng et al., 2022; Harvey & Schnur, 2016; Schnur 2014). Indeed, the semantic interference is also present when novel related pictures are tested that is not part of the original picture set (Belke et al., 2005; Harvey & Schnur, 2016; Oppenheim, 2018) and increases in magnitude when the pictures are more related in the homogeneous blocks (Vigliocco et al., 2002). In this mode of presentation, the interference effect is only present after the first cycle but does not typically build in size after the second cycle (Belke et al., 2005). This has led some to suggest that the 'cumulative' part of the CSI effect is something of a misnomer (Belke & Stielow, 2013), though this thesis will continue to use this common terminology.

Beyond blocking of related and unrelated concepts, CSI effect can also emerge in a continuous presentation of pictures, where participants have to name the pictures consecutively (Howard, et al., 2006). Specifically, the naming of an item in a category will slow down the naming of another exemplar of the same category. For example, in naming a series of pictures of; CAT, TRAIN, DOG, TRUMPET, CAR, GOAT, the reaction time to correctly name DOG after previously naming CAT will increase compared to CAR or TRUMPET. The reaction time for naming GOAT later in the series will also be longer than that for naming DOG. This cumulative slowness of the reaction time is the main effect of CSI. It should be noted that CAT, DOG, and GOAT belong to the animal category (Howard et al., 2006; Oppenheim et al., 2010). Importantly, this slowness is not due to fatigue, as naming latencies do not consistently increase as the series continues.

CSI has been commonly used to investigate the structure of a language, particularly in language production studies (Riley et al., 2015). It can also investigate the categorisation of concepts, such that items that are semantically related will interfere with one another more than items that are unrelated. This means that concepts that do not show a CSI effect may not be closely related to one another in semantic memory. Hence, this is a useful paradigm for investigating category structure in semantic memory (McCarthy & Kartsounis, 2000; Schnur et al. 2006; Harvey & Schnur, 2016; Roelofs, 2018; Wilshire & McCarthy, 2002). Studies have also suggested that interference may occur exclusively at the conceptual level. These studies tend to employ a range of tasks such as picture matching tasks (Belke & Stielow; Harvey & Schnur, 2015), and studies in bilingual populations (Döring et al., 2022). It has also been used to investigate the impairments and functional capability of patients with mild cognitive impairment and aphasia (Mulatti et al., 2014; Harvey et al., 2019).

A number of mechanisms for the interference have been proposed. One such account uses a connectionist model and highlights the role of shared activation, priming, and competition during lexical selection (Damian et al., 2001; Howard et al., 2006). It will be briefly discussed here.

When a concept needs to be retrieved, activation for that concept needs to occur. As concepts do not exist in a vacuum in the semantic space, similar concepts would also be co-activated. Representing the word CAT inadvertently activates the representation of the DOG because they share similar properties. This is known as the shared activation of concepts. The activation could also spread not only to CAT and DOG, but also to other concepts that are also within the category of animals. Activation is said to have spread to other associated concepts (Colin & Loftus, 1975). Theorists described how the residual activation of semantically related concepts (e.g., naming CAT activating the concept of animals such as DOG) competes with the subsequent naming of the new target words (Damian et al., 2001; Howard et al., 2006). Concepts that were the target now become the competitor of the subsequent target. As a series of naming occurs, more concepts will be activated, and hence more competitors will interfere with the selection of the appropriate lemma of the pictures. This leads to a roughly linear increase in naming latency.

Alternatively, Oppenheim et al. (2010) argued through using computational modelling that CSI is not due to competitive lexical selection, but due to concurrent strengthening of lexicosemantic target pictures and the weakening of links between the lexicosemantic properties of the non-target items through a learning mechanism. This means that correctly naming CAT strengthens the links between the concept of CAT and the lexical entry of CAT and other associated concepts. This also means that the links between the lexical entry of the DOG and the concept of the DOG are weakened. When the concept of the DOG is later retrieved when it becomes the target, the weakened link requires more effort to pass the threshold of being selected as the correct name of the picture being presented. Regardless, both theories agreed that the degree of CSI depends on the strength of the semantic relationship between competitors. This makes the CSI paradigm an appropriate one for studying the degree to which affective valence influences the semantic relationships between concepts. This is the aim of **Chapter 3**.

1.8.2 **Visual World Paradigm**

To investigate whether people use emotional information predictively in sentence comprehension, in **Chapter 4**, I used the visual world paradigm. The visual world paradigm is a method that uses eye-tracking to determine when people predictively activate specific concepts during language comprehension (Altmann & Kamide, 1999). Prediction has long been thought to play an important role in language processing (for reviews, see Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). Simply put, prediction is the means to activate a specific representation of a concept before encountering the concepts themselves and the visual world paradigm is one such method that can confidently show this effect (Pickering & Gambi, 2018). My review in previous sections suggests that emotional concepts are automatically activated and can be important in language processing, but none made specific conclusions regarding when and how emotional information influences prediction. After all, many of our linguistic interactions involve discussions of social interactions or stories about how people behave or react in different situations (Barrett & Wrestlin, 2021). To date, no study has specifically investigated how emotional information is used in prediction. The visual world paradigm shows promise for answering this question.

The first study that combines eye-tracking and concurrent sentence processing was a study conducted by Cooper (1974). It was then popularised in the field of psycholinguistic by a seminal study by Tanenhaus et al. (1995). The term visual world paradigm was then coined by Allopenna et al. (1998) and has been used ever since. In this paradigm, the listener is presented with a visual scene while hearing an utterance. Listener's eye-movements are then recorded. The critical finding is that around 0 to 200 ms after the word onset, around 90% of the trials, the eye-movements are time-locked to the linguistic information that are presented (Cooper, 1974). Tanenhaus et al. (1995) also instructed listeners to perform a simple task while their eye movements were recorded. They found that instructing participants to "Touch the starred yellow square", more saccadic eye-movements were made to target objects as the sentences unfolds (e.g., listener were more likely to look yellow objects in their visual field after they heard the word yellow compared to a green object). Even with complex instructions, saccadic eye movements still mirrored each object in their visual field each time they were mentioned in the sentences. While it was obvious that people will look at the relevant objects when instructed, the key finding that people do so in a rapid manner and time-locked to the sentence content in real-time, is important.

The effect also extends to normal sentence comprehension. For example, participant is more likely to look at a dog while hearing "The name of the dog is…".

The most probable theory that is used to support the findings using this paradigm is the constraints-based theory (Huetig et al., 2011). This theory suggests multiple interpretations of the meaning of the sentence are all available to the comprehender which undergo activation or inhibition following specific constraints such as linguistic (e.g., lexical influences, verb category) or non-linguistic (e.g., prosody) information (MacDonald et al., 1994; Trueswell et al., 1994). This provides psycholinguists a tool to investigate how and when linguistic and non-linguistic information are used during sentence comprehension.

Altman and colleagues used the visual world paradigm to investigate how specific aspects of linguistic levels contribute to sentence comprehension predictively. In a seminal study, Altman and Kamide (1999) presented the participants with a visual scene consisting of a boy, cake, and various other objects. The participants then heard a sentence being read out "*The boy will eat the cake*" or "*The boy will move the cake"*. More saccadic eye movements were given to the target word *cake* when the subsequent verb was *eat* compared to *move* before they heard the word *cake*. They reasoned their result as supporting comprehension by prediction. This is because the target word *cake* was the only edible object in the visual scene, the verb *eat* restricted the participant's reference to edible objects. They suggested that as the sentence unfolds, people predicted the upcoming information based on the prior context, in the case of this study, the semantic features of the target word. Later studies revelated that these contexts can also include other linguistic information such as grammatical subject (Kamide et al., 2003), tenses (Altmann & Kamide, 2007), form (Ito et al., 2018), or even non-linguistic information (Corps et al., 2022; Cao et al., 2023). Altmann and Kamide (2009) further showed that the listeners dynamically build an event representation or situation model while processing the utterances. Thus, the visual world paradigm is an ideal method for investigating what types of information contribute to predictive processing and when they do so. However, none have used the visual world paradigm to examine whether people make predictions using the emotional content provided in the prior context. This is the aim of **Chapter 4**.

1.9 **Current thesis**

I return to each of the specific questions in the following chapters. In short, I sought to answer outstanding questions in psycholinguistics regarding how emotional information plays a role in various levels of language processing using multiple psycholinguistic paradigms. Note that I am not attempting to address all the outstanding questions I present in this chapter as the main focus is to demonstrate the potential trajectory in investigating the interaction between language and emotion.

So far, I have identified three main questions which will be explored in my three experimental chapters. In short, **chapter 2** reports 3 experiments using modality switching paradigm to investigate how emotional processing differ from non-emotional processing. **Chapter 3** reports 2 experiments utilising Cumulative semantic interference to investigate whether emotional information is an important organising principle for concrete objects. **Chapter 4** reports 1 experiment using visual world paradigm to investigate how and when does the emotional state of an agent contribute to the prediction of sentence comprehension. Finally, **Chapter 5** discusses the implication of these findings alongside recent theories and potential future directions.

Chapter 2: To think or feel: Are there processing cost when switching between emotion and cognitive sentences?

2.1 **Abstract**

The modality switching paradigm investigates the proposal that concepts from different modalities can incur processing costs when they are switched. The paradigm's logic is as follows: verifying concepts from one modality (e.g., auditory modality) after processing in a different modality (e.g., visual modality) is slower compared to verifying concepts from the same modality repeatedly. Many studies have investigated this phenomenon in concrete concepts (e.g., apples, blenders) while few studies have focused on concepts that refer to interoceptive experiences, which includes emotional and non-emotional concepts. Thus, the current interest of this study is concerning internal experiences, which recently has been a main focus in the literature (e.g., Connell et al., 2017). We report 3 experiments that use the modality-switching paradigm to investigate whether there are processing costs (hereby regarded as switch costs), when one switches between affective and cognitive concepts. Study 1 investigated the switch cost between sentences describing internal (interoceptive) emotional and cognitive states. Study 2 extended this approach to investigate external (observable) states, while also replicating a previous study that investigated the switch cost between external and internal experiences. Finally, Study 3 focused exclusively on the switch cost when the sentences described externally observed emotion and cognitive states. Our results suggest that there is no switch cost for either internal or external descriptions. We conclude that our data supports weaker embodiment theory.

2.2 **Introduction**

Our external world consists of stimuli from different modalities. We perceive these stimuli using different sensory modalities. For example, we can see the looming clouds, feel the sensation of rain on our skin, hear the thunderous roar and smell the petrichor after the storm. Indeed, each of these events are processed by their specialised modalities. For example, visual cortex is associated with processing visual stimuli and auditory region with processing sounds (Keitel, Gross & Kayser, 2020). What happens when you read about these events, how are the concepts of these events represented in our cognitive system when you attempt to comprehend them? Embodied cognition theories suggests that these external experiences are represented in our internal, cognitive world by the means of grounding it in our modality-specific sensorimotor regions (e.g., Barsalou, 1999; 2008). Specifically, embodied cognition claims that we understand descriptions of sensorimotor experiences by simulating those experiences using the same neural systems that support perception and action. However, how are we representing the concepts that are not bound by our sensory modalities, for example our internal experiences of thinking and feeling? Less is understood about how we represent and comprehend these concepts that are not readily apparent in the physical world.

Seminal works by Barsalou (1999; 2008) highlights the role of sensorimotor regions in grounding concepts that we acquire in the world. Within the embodiment literature, theorists often engage in the debate on the extent to which a concept can be embodied. Meteyard et al., (2012) claimed that embodiment theories exist in a continuum. They posit that the main distinguishing factor between these embodiment theories is the strength with which semantic content is linked with the sensorimotor system. A strong embodied account suggests that sensorimotor regions are activated automatically (e.g., Gallese & Lakoff, 2005; Pulvermuller, 1999). Theorists holding this view argue that semantic representation is heavily dependent on the sensorimotor regions. Conversely, weak embodiment accounts claim that semantic representations are less dependent on sensorimotor regions. Instead, sensorimotor areas have associative links with defined semantic regions through amodal regions or convergence zones (Damasio, 1989). Specifically, weak embodiment defines a distributed networks of regions that codes for either amodal semantic information or modality-specific information (Mahon & Caramazza, 2008; Patterson et al, 2007: Bersalou, 1999; Pulvermuller, 1999; Vigliocco et al., 2004). While both accounts of embodiment share fundamental ideas, the weak embodiment approach is often more strongly supported by neurobiological evidence (See Meteyard et al., 2012 for review). Importantly, a direct referent to the real world is necessary to activate these sensorimotor representation (e.g., hearing the word chair may activate visual simulations of the appearance of chairs). Therefore, concepts that have no external referents such as abstract concepts have traditionally represented a challenge to embodiment theories (see Dove, 2009 for review). However, recent researchers have tried to provide a parsimonious response to this challenge (Borghi et al, 2017; Tirado et al., 2018). Indeed, research has begun to investigate the role that embodiment plays in grounding abstract concepts (Borghi et al., 2017).

Abstract concepts are often discussed as concepts that have difficulty in being grounded compared to concrete concepts (Tirado et al., 2018). Refer to our previous question; how do we represent our internal experiences, such as thinking and feeling? These internal experiences are considered as mental states, in that they occur solely in our internal world (e.g., I think/I am happy my next move can lead me to a checkmate). This means that people simulate their own internal, interoceptive states when they are experiencing the mental events. Additionally, mental states can be observed externally when we see or hear other people experiencing them (e.g., The chess player thought of his next move by rubbing his chin/scratching his head). This means that people simulate their external perceptual states that they experience when they encounter mental events. This poses a problem as embodiment theories, in this case, cannot rely solely on somatosensory and sensorimotor systems. Conversely, arguments have been made to support the grounding of external mental states. Specifically, grounding of emotional concepts is argued to be possible due to various actions that are associated with it. For example, external elements that are associated with emotional state includes body posture (e.g., Aviezer et al., 2012), facial expression (e.g., Ekman & Friesen, 1971), and approach or withdrawal tendencies (e.g., Frijda, 1986). Additionally, researchers turn to other ways of understanding abstract concepts, such as using temporal and spatial context (e.g., Margolies & Crawford, 2008), or language and social experience to ground them (see Borghi et al., 2017 for review). Kosslyn et al., (2001) argued that imagining emotions could lead to reactivation of neural substrate associated with feeling the emotion itself. There is also evidence that abstract concepts can be grounded in our five senses, akin to concrete concepts. Some examples include moral judgement being able to modulate gustatory taste (Eskine et al., 2011), valenced concepts associated with the position of the body (Casasanto, 2009), and emotional valence associated with temporal and spatial space (Margolies & Crawford, 2008). These series of studies have shown that abstract concepts can be grounded in other ways but also highlights the complexity of investigating embodiment in abstract concepts.

Recently, the role of interoception, or sensations in our body is also argued to be important in grounding abstract and even concrete concepts (Connell et al., 2018; see Critchley & Garfinkel, 2017 for review). This dimension involves mental, visceral and affective concepts. Various studies have demonstrated that our internal experiences consist of distinct processes which includes emotion (e.g., happy, sad), cognitive (e.g., concentrate, thinking) and visceral states like dizzy and hungry (von Helversen et al., 2009; Barrett & Bar, 2009; Oosterwijk et al., 2012). Words like convince or truth recruit complex processing areas such as medial prefrontal cortex (Wilson-Mendenhall et al., 2013; Dreyer et al., 2015; Moseley et al., 2012). Harpaintner et al., (2020) further showed that abstract concepts that refer to perception (e.g., beauty) will also activate visual regions. In a neuroimaging study, the researcher asked the participants to passively view emotional (e.g., love, hate) and mental nouns (e.g., thought, logic). They found that face and motor areas were activated more in viewing abstract words than concrete words (Dreyer & Pulvermuller, 2018). The authors further suggests that purely mental words that are devoid of affect, like logic and synergy, are grounded in the articulatory motor regions within the face regions as they are grounded in the act of articulating the word itself. A study by Borghi and Zarcone (2016) supported this. In their experiment, they asked participants to press a key using their hands or using their mouth when they saw a congruent pairing of concrete and abstract words to its descriptions. Critically, they found that for concrete words, responding with hands were faster than responding with mouth. This finding upheld the theory called Words as Social Tool (WAT; Borghi and Binkofski, 2014). This proposal indicates that abstract words are more prominently embedded in affective and linguistic system than the sensorimotor system, although they maintain the argument that abstract words can still be embodied in latter system to some extent.

The role of emotion is important in relation to concepts that refers to our internal world. Kousta et al. (2011) showed that abstract words are more associated with their valence than concrete words. They argued that this could lead to a processing advantage in a lexical decision task, when both of these categories were controlled for their imageability, context availability and mode of acquisition (although see Imbir et al., 2020). Vigliocco et al. (2014) corroborated this finding with neuroimaging evidence that abstract words engage more affective areas in the brain compared to concrete words. While many neuroimaging studies found a greater engagement of linguistic regions during abstract words processing (Binder et al., 2009; Paivio, 2007), the two studies described above highlight the additional role of affect in grounding abstract concepts. Further, evidence suggests that people make a distinction between emotional and non-emotional word. Indeed, Barsalou and Wiener-Hastings (2005) highlighted the role of introspective states such as mental and affective states to ground abstract concepts. These studies reviewed above suggest that abstract concepts are modulated by their degree of affect. This includes both subjective and introspective experiences (Schwarz & Clore, 2007).

However, none of the studies reviewed above have investigated whether there is a behavioural difference between abstract concepts that refer to emotion compared with those that refer to non-emotional mental states. If affect is important in grounding our understanding of emotional mental states, how are non-emotional mental states grounded? This question is difficult to answer because most literature has focused on studying emotions directly (e.g., Glenberg et al., 2009) or has compared large and general classes of concrete and abstract concepts (see Borghi, 2022 for review). There is evidence that the semantic representation of emotion concepts differs fundamentally from non-emotion concepts. For example, Espey et al., (2023) trained people with novel abstract concepts: they found that people were able to produce more emotional features when the novel abstract concepts were emotional and more cognitive features when they were classified as neutral concepts. A question could be asked then: If emotion concepts involve simulating emotional states, what do non-emotional abstract concepts, like cognitive concepts simulate? No studies so far have directly shown whether simulation of emotional and cognitive concepts involves different processes. Specifically, how exactly are concepts that are not emotional, but also contains interoceptive elements such as 'thinking' or 'meditating' represented?

A way to investigate these questions is by using switching paradigms similar to that used by Glenberg (2009). Embodied cognition studies have frequently investigated switch costs between processing semantic information relating to different sensorimotor modalities. The paradigm was based on a pure perception study by Spence, Nicholls and Driver (2001). In this study, participants were tasked to identify whether a signal of differing modalities (e.g., flashing lights for visual, beeps for auditory) came from the left or right side of their position. They found that people were slower to identify the signals when the previous trial was from a different modality (switch trial) compared to the same modality (same trial). They argued that participants had to switch their attention between the modalities on these trials, and that switching incurred a cost in reaction time. Glenberg (2009) highlighted that congruence between a person's emotional states and the content of an emotional sentences facilitates the speed of comprehending the sentence. They argued that reading emotional sentences simulate the corresponding emotional state. Hence, when one switches between comprehending sentences that described different emotional states, they were slower compared to when they comprehend consecutive sentences that described similar emotional states. This switching effect can enable us to understand how emotion concepts is simulated differently from cognitive concepts.

Various studies have shown that concepts from different modalities, represented linguistically, can show a similar switching effect. Pecher and Zeleenberg (2003) conducted a study to test the hypothesis of conceptual switching costs using a property verification task. Here, they asked the participants to decide whether a characteristic of the objects was true or otherwise. The properties were manipulated such that they were experienced in different sensory modalities. For example, a lemon could be yellow or could taste sour. They found that trials where people had to switch between verifying properties in different modalities, caused a processing cost. For example, people were slower to verify that "a blender can be loud" (auditory modality) after verifying that "a lemon can be yellow" (visual modality) than after verifying that "a bird can chirp" (auditory modality). The authors using this paradigm have taken these findings as evidence that people simulate perceptual experiences when processing semantic information and that there are costs when switching between different types of simulation.

Furthermore, Vermeulen et al., (2006) showed that the same cost could also be observed when one switched between these perceptual and affective properties. For example, following verifying "a victim can be stricken" (affective modality), people were slower to verify "A cheddar can be orange" (perceptual modality) compared to "An orphan can be hopeless". The authors argued that this was evidence for concepts being grounded in emotion as well as action and perception. In their study, they considered affective systems being different from perceptual modalities, as they showed switching cost. They reasoned that this is due to the shift of attention to process concepts that belong to a different modality. However, they did not discriminate between different type of abstract concepts, in particular the difference between emotional and non-emotional abstract concepts.

A more recent experiment alluded to the differences between emotional and non-emotional concepts. Oosterwijk et al. (2012) used plausibility judgement task to investigate whether there is a switch cost between introspective states described from the external perspective of an observer (e.g., “She frowned when she was sad”) compared to states described from the internal perspective of the experiencer (e.g., “Her stomach turned with fear”). They found switch cost effect when people switch between external focused sentences to internal focused sentences. For example, people verified the sentence “Her chest swelled with pride” (external focused sentence) slower after the sentence “Her mouth went dry with fear” (internal focused sentence) than after verifying “She imagined her future in silence” (external focused sentence). Importantly, they are interested in the difference between internal and external experience of introspective experiences. In doing so, they used different type of abstract sentences, varied in their focus. The authors claimed that this provides evidence that perceptual experiences (external) are processed different to interoceptive experiences (internal).

Oosterwijk et al. (2012) used emotional, cognitive and visceral sentences. Their reasoning for including these types of sentences was to avoid a priming effect that might occur when processing two emotion sentences in a row. Therefore, all of their sentence pairs differed in their emotionality (whether they are emotional or cognitive or visceral). As a result, their design did not allow them to investigate whether there are any processing costs when switching between emotion and non-emotion interoceptive experiences. Modality switching paradigm is useful to identify the relationship of concepts and the modality required to process it. Coupled with the review from the previous section, an interesting question to ask is whether emotional sentences are processed differently from non-emotional sentences. If there is a switch cost between emotion and non-emotional sentences, this indicates that emotion sentences are processed through a different mechanism to cognitive sentences. On an embodied account cognition account, this would suggest that cognitive states are simulated using a different system to emotion states. Therefore, we could extend the evidence for semantic switching costs beyond the perception-interoception distinction and into different types of interoceptive experience.

The current study attempts to answer the question we have outlined, whether interoceptive states which we define as emotional or cognitive are processed differently from each other? Specifically, we are interested in whether people's reaction times are influenced when they switch between emotional and cognitive sentences. As there are no previous studies that have investigated this relationship within the embodiment literature, our finding would be novel and can contribute to the understanding of how exactly emotional information is used in comprehending emotional sentences. We hypothesise that there is a processing cost when one switches between processing sentences that describe emotional events (e.g., "The fleeting moment saddened her") and cognitive events (e.g., "The current time confused her"). We will test whether the classic switch cost effect (e.g., Pecher et al, 2003) will be observed when one comprehends a congruent pair of emotional or cognitive sentences compared to incongruent sentence pair.

2.3 Experiment 1 - Switching cost between emotion and cognitive sentences described internal perspective.

2.3.1 **Methods**

2.3.2.1 **Participants**

To determine the required sample size, we obtained the estimated effect size from Oosterwijk et al. (2012), which we had based our stimuli on. Their study investigated the effects of the switching between external focused sentences and internal focused sentences. The size of the switching effect in this study was Cohen's d = 0.21. At 80% power, to detect a similar effect, we would need 141 participants. These are calculated using a program called G*Power (Faul et al., 2009)

167 participants completed the task. 39 people were removed as they did not pass the 80% accuracy threshold. Therefore, only 128 [$Mean_{age}$ =22.84, $Mean_{sd}$=4.33, female = 76] were included in the final analysis. Participants were recruited from three

sources: undergraduate students from the University of Edinburgh, online Testable and Prolific pools. All participants were native English speakers, spoke English before the age of 5 and currently living in the United Kingdom. All participants were reimbursed with money or study credit for their participation. Informed consent in accordance with the Philosophy, Psychology Research ethics committee (PPLSREC) guidelines was obtained from each participant.

2.3.2.2 **Stimuli**

We created our stimuli by adapting the sentences used by Oosterwijk et al. (2012). We created sentences in which the agents of the sentences experience mental states that were either emotional or cognitive in nature. Emotional sentences were sentences that refer to an emotional event or mental state (e.g., “The fleeting moment saddened her”), whereas cognitive sentences were sentences that described cognitive mental states or events (e.g., “after the lecture her mind was spinning”). We only selected sentences that were categorised as internal in Oosterwijk’s dataset, meaning that they described the introspective experience of the agent (e.g., “the compliment made him proud”), as opposed to external sentences which described how the agent appears to others (e.g., “she waved her arms ecstatically “).

Oosterwijk et al. (2012)’s stimuli consisted of three types of internal sentences: emotional, cognitive, and visceral, where visceral sentences referred to states that represent basic reaction to biological desires (e.g., tired, hungry, famished). As these sentences cannot be unambiguously categorised as emotional or cognitive, we did not include them. In total, 50 emotion sentences and 50 cognitive sentences from Oosterwijk et al. (2012) were selected. To expand on their stimuli, we constructed an additional 100 sentences (50 emotion and 50 cognitive sentences) totalling to 200 sentences. From the 200 sentences, we generated another 200 sentences that were similar in their length and grammatical structures. We did this by changing the emotion sentences into its cognitive counterpart and vice versa. For example, the emotional sentence “He was sick with disgust” was changed to “He was bewildered with confusion”. Likewise, a cognitive sentence of “After the lecture, her mind was spinning” was changed to “After the scolding, she was mad”.

There were two types of sentences: prime and target sentences. The sentences were paired to measure the switching effect. A switch pair was when the prime sentences had different modality than the target sentences, while a same pair was when both prime and target had the same modality (Full stimuli in Appendix). The sentences were paired in such way that half of the sentences were in switch pairs and another half were in same pairs.

The sentences were normed by 18 participants ($Mean_{age}$ 26.39, 7 females) not involved in the main experiment, who rated each sentence on a scale of 1 (highly non-emotional) to 7 (highly emotional). Following this, 112 sentences were removed. The removal of these sentences was due to following criteria: They were rated opposite to their expected emotionality (e.g., “He was sick with disgust” were rated as 1) or had small differences between the matched sentence equivalents (e.g., “He was sick with disgust” were rated 4 and “He was bewildered with confusion” was rated at 3.9). That left us with 288 introspective sentences (144 pairs). A Paired t-test was conducted on the final set of sentences. There was a significant difference between sentences that were emotional (mean=5.37, sd =0.67) and cognitive (mean =2.99, sd = 0.91), [t(144) = -33.743, p .001].

We also included 320 filler sentences, taken from the Oosterwijk et al., 2012 stimuli set. The sentence pair was left unchanged and was kept consistent with Oosterwijk et al. (2012). An example of a sensible filler sentence would be “he is sentenced with a mild punishment”. For non-sensible sentences, one example would be “she came over to drink puzzlement”. The critical introspective sentences were all semantically plausible sentences (represented by YES) while the filler sentences set contained 75% of semantically implausible sentences (represented by NO). Specifically, there were 50 YES-NO pairs, 50 NO-YES pairs and 100 NO-NO pairs, resulting in 200 pairs of sentences. There was a comparable number of plausible and implausible sentences in the experiment.

2.3.2.3 **Design**

The sentences were structured such that a trial consisted of two sentences presented sequentially as a pair, where the preceding sentences being the ‘prime’ and the later sentence being the ‘target’. This organization was unknown to participants as they had to make a judgement about each sentence presented serially. We used a 2 x 2 design, manipulating the emotionality of the target sentence (cognitive vs. emotional) and switching (whether prime was the same sentence type as the target (same) or a different type (switch). Participants were asked to judge sentence sensibility, as per the sensibility judgment task used in Oosterwijk's, et al. (2012).

Table 1 shows some examples of the sentences. Two different lists of sentences were presented to different groups of participants. Each lists contained the same target sentences, but the assignment of primes was counterbalanced such that each target sentences appeared in switch condition in List A and same conditions in list B. Overall, each participants saw an equal number of switch and same targets and equal number of emotional and cognitive sentences. Pairs of fillers sentences were also included and randomised. This design allowed counterbalancing between the sentences and ensured that the effect we observed was due to the change of emotionality of the sentence. The counterbalanced design allowed each participant to observe the same targets but with different prime sentences. The same design was used for all of our experiment.

Table 1

Summary of the design. Same represents Emotion-Cognitive/Cognitive-Emotion pairs. Switch represents Emotion-Emotion/Cognitive-Cognitive pairs.

	List 1	List 2
Pair 1 Emotion target	He was sick with disgust. **After the scolding she was mad.** *(same)*	He was bewildered by confusion. **After the scolding she was mad** *(switch)*
Pair 2 Cognitive target	He was bewildered by confusion. **After the lecture her mind was spinning**. *(same)*	He was sick with disgust. **After the lecture her mind was spinning**. *(switch)*
Pair 3 Cognitive target	Guilt was felt by him after he left. **She was starting to doubt her assumption**. *(switch)*	Confusion was felt by him after he left. **She was starting to doubt her assumption** *(same)*
Pair 4 Emotion target	Confusion was felt by him after he left. **She was starting to cry herself to sleep**. *(switch)*	Guilt was felt by him after he left. **She was starting to cry herself to sleep**. *(same)*

2.3.2.4 **Procedure**

Figure 1 shows the procedure of each trial. In each trial, participants observed a fixation point for 500 ms, followed by a sentence presented in the middle of the screen for a maximum of 4500 ms. Participants were required to decide whether the sentences they saw were plausible or not. Plausibility was defined as whether the sentences were sensible to be heard in a normal setting. They responded by pressing 'Z' or 'M' keys. The trial ended when a response was made or when 4500 ms had elapsed. There was an interstimulus interval for 1000ms.

There was 1 practice block, where participants were given 16 sentences that were not included in the main block. For the main experiment, there were 4 blocks of 152 trials with a short break after every block. Participants were given feedbacks when they were too slow or made an error.

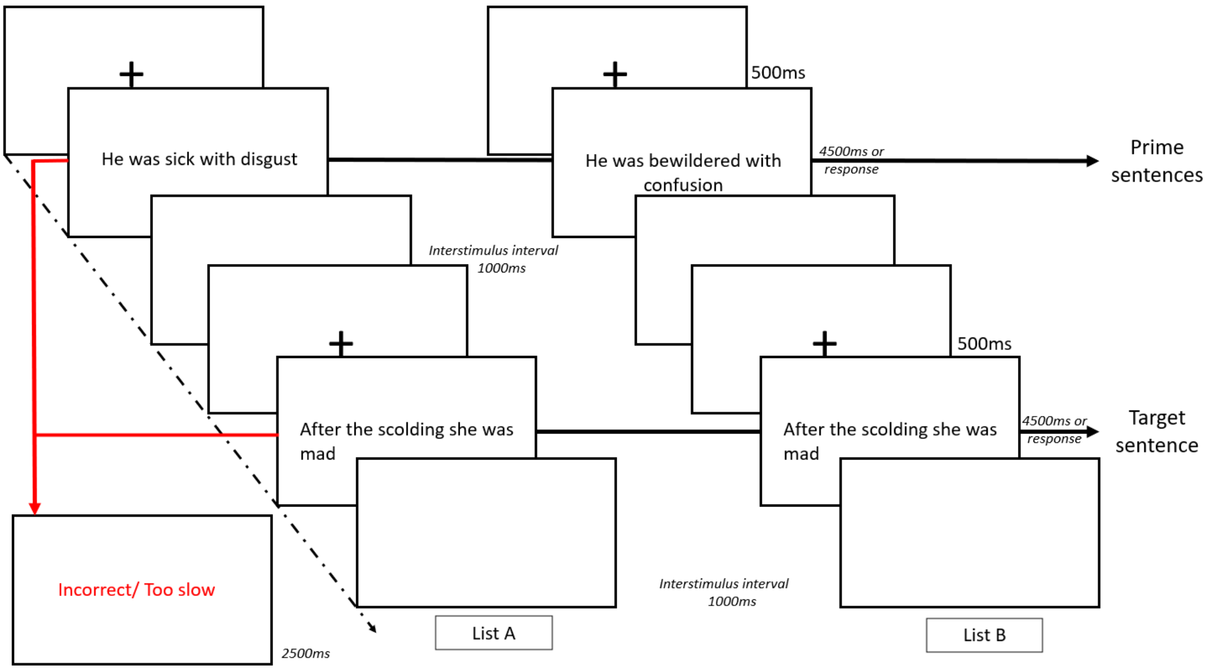

Figure 1 Illustration of a trial in the experiment.

2.3.2.5 **Analysis**

All of our analysis were conducted using R-studio (version 2023.03.1+446). Reaction times were standardised using the winsorising method (Reifman & Keyton, 2010). Extreme values that were more than 2 standard deviations away from the participants' overall mean were replaced with the 2 standard deviation value. This process was used in all the subsequent experiments unless stated otherwise. We excluded participants that had less than 80% accuracy.

The data was analysed using R packages lme4 (Bates et al., 2015) using logistic (accuracy) and linear (RT) mixed models (Baayen, Davidson, & Bates, 2008). Our main analysis focused on RTs to critical target sentences, including only those trials where participants responded correctly to both prime and target sentences. Our mixed model analysis included emotionality and switching as fixed effects and the random effects of participants and sentences. We began with a maximal model that included random slopes for all fixed effects (Barr, 2013). Sometimes maximal model failed to converge as the mixed effect structure is too complicated or took too long to converge. We took the following steps until we obtained a model that converged using the following pipeline: 1. Removed correlations between random effects, 2. Removed random slopes for sentences, 3. Removed random slopes for participants. We discussed the final model in the result section.

2.3.2 **Results**

Table 2 shows the average reaction times (RT) and accuracies of prime sentences and target sentences. **Figure 2** shows the average RT in millisecond for cognitive and emotion sentences broken down by their sentence types with error bars representing standard deviation. Participants have similar RTs for prime and target sentences and were generally accurate.

Table 2

Descriptive statistic of each sentence type.

sentence type	Reaction time (ms)			Accuracy	
	n	*mean*	*sd*	*%*	*sd*
Prime	18432	1192	180	91	3
Target	18432	1184	184	93	3

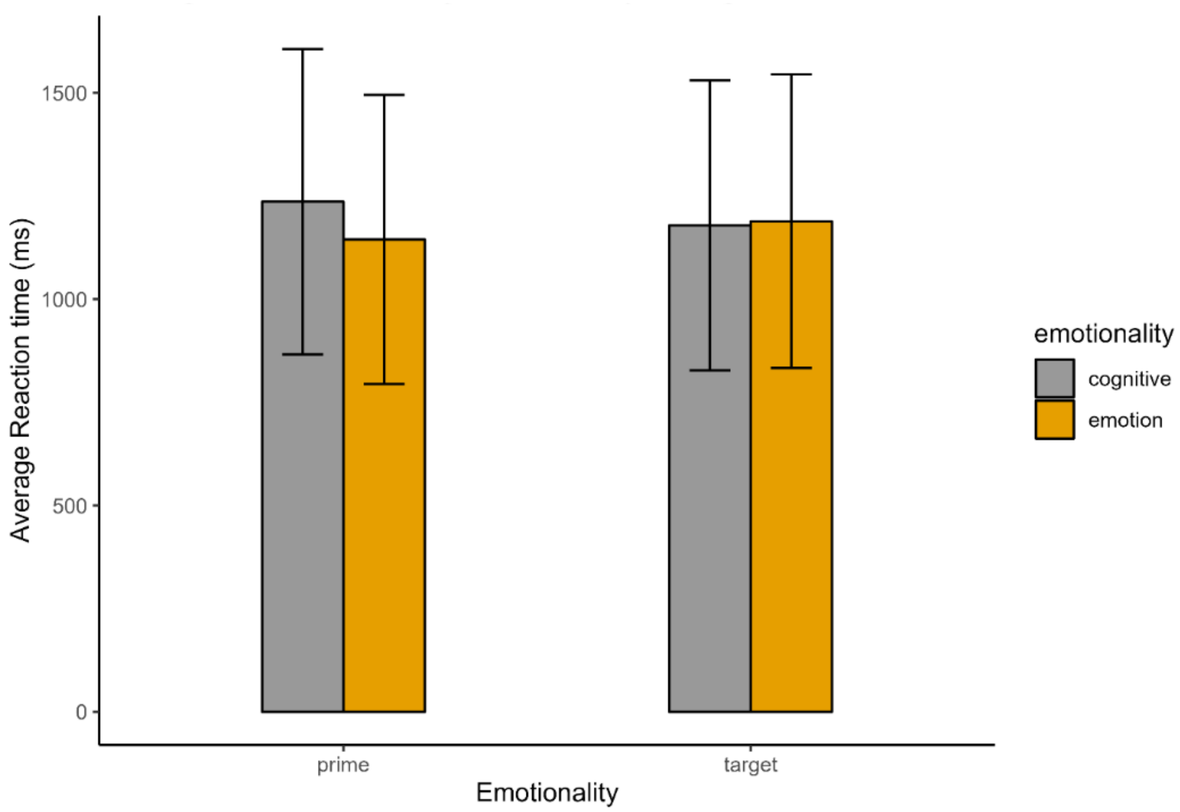

Figure 2 Plot of average reaction time between cognitive and emotion sentence broken down by the sentence type. The error bars represent standard deviation.

Table 3 shows the RTs and accuracies for each emotionality of target sentences. In general, participants show faster response time in verifying cognitive sentences than emotion sentences [t(9215)=-2.32, p=0.021].

Table 3

Descriptive statistic of for each emotion group in target sentences only

Emotionality	Reaction time (ms)			correct	
	n	mean	sd	%	sd
Cognitive	9216	1179	182	94	3
Emotion	9216	1189	189	92	4

Figure 3 and **Table 4** shows the average reaction time for the switching manipulation broken down by the emotionality of the target sentences in correct trials (both prime and target sentences are correct).

Table 4

Descriptive statistic of for each condition trial by emotionality in target sentences only.

Emotionality	Conditions	Mean (ms)	sd	se
Cognitive	same	1156	184	16
	switch	1156	183	16
Emotion	same	1161	189	17
	switch	1156	191	17

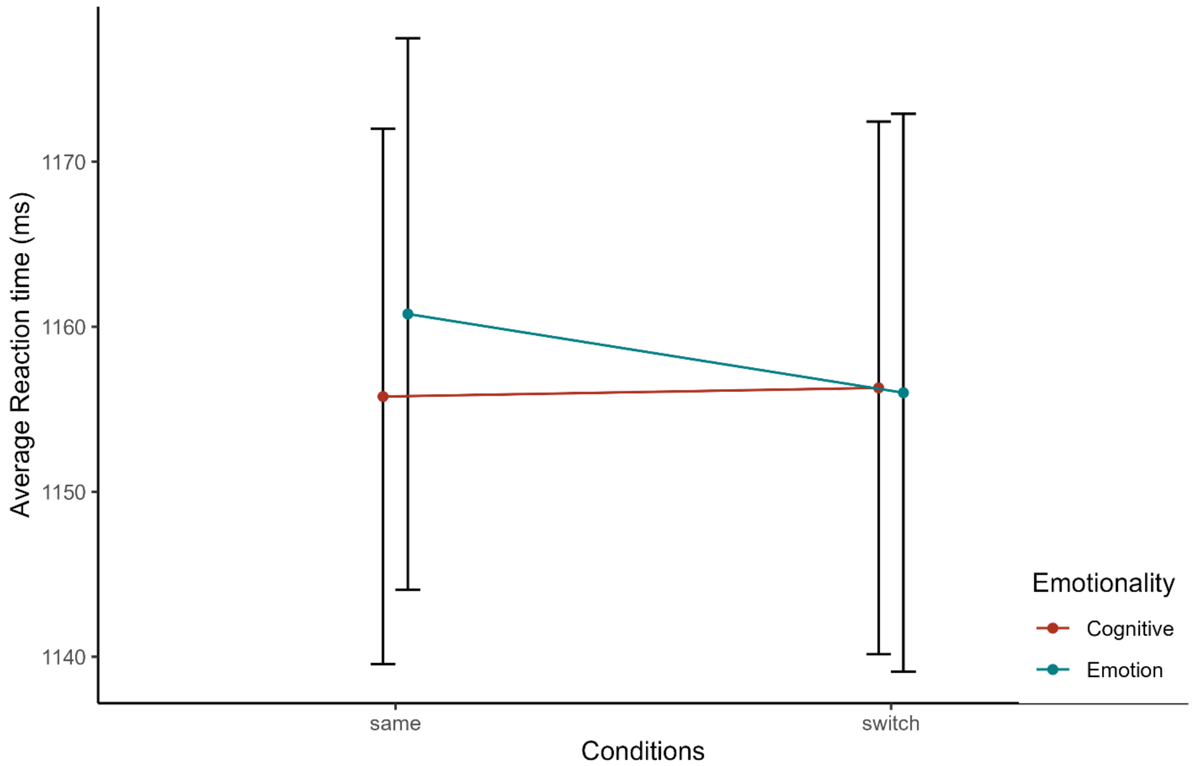

Figure 3 Average reaction time between the two conditions (same and switch) and the emotionality. Error bars represent standard error of the mean.

For our main analysis, we fitted a linear mixed model to predict participant's reaction time and accuracies against the interaction of emotionality of the target sentence and the switching effect. The model included random intercepts and slopes of interaction of emotionality and switching as random effects for participants, and random intercepts and random slopes of switching for sentence. **Table 5** shows the model parameters for participants' RT and **Table 6** shows the model parameters for participants' accuracies.

Table 5

Summary of the reaction times examining the effects switching and target's emotionality

	Reaction time			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	1166.04	21.36	1124.17 : 1207.90	**<0.001**
Switching	-0.15	2.16	-4.38 : 4.09	0.946
Emotionality	-2.16	14.12	-29.83 :25.51	0.879
Switching * Emotionality	-1.34	2.30	-5.85 : 3.17	0.561

Table 6

Summary of accuracies of the mixed models examining the effects switching and target's emotionality.

	Accuracy			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	3.23	0.13	2.98 : 3.48	**<0.001**
Emotionality	0.25	0.12	0.01 : 0.49	**0.041**
Switching	0.02	0.03	-0.04 : 0.08	0.483
Switching * Emotionality	0.02	0.03	-0.05 : 0.08	0.613
Marginal R^2 / Conditional R^2	0.012 / 0.385			

There is no main effect of emotionality on participants' reaction time. This means that there is no difference between emotional and cognitive sentences, suggesting that these sentences were well-matched in difficulty. However, there is a main of effect of emotionality in participant's accuracies. This means that, participants were slightly more accurate in verifying cognitive sentences.

Importantly, there is no main effect of switching and no interaction with emotionality for either RT or accuracy. This means that the switching effect is not observed when the target was either an emotional or a cognitive sentence. This goes against our hypothesis that suggests that there would be a switching effect when switching from an emotional to cognitive sentences or vice versa.

2.3.3 **Discussion**

In this experiment, we investigate whether there is a switching effect when switching between emotional and cognitive sentences that describe experiences from an internal focus. We were interested in understanding whether emotional sentences engaged different processing mechanism compared to cognitive sentences. If this is true, we would expect a switching cost when people switch between two types of introspective sentences. We could not find such effect in Experiment 1.

We propose 2 possible explanations for the lack of effects in our data. First, people did not experience switch cost at all when they move from cognitive to emotional sentences or vice versa when the sentences were describing introspective experiences. This could suggest that people simulate these mental events similarly, even when they differ in emotional content. It would be interesting to investigate whether there is any switch cost in sentences describing these mental events from an external perspective, as people could also observe people experiencing these mental events through their overt behaviour (Oosterwijk et al., 2012). Secondly, it could be the case that our experimental procedure did not have the sensitivity to detect switching effects in general. As the study was conducted online, this might lead to less accurate measurement of RTs and therefore lower sensitive to subtle effect compared to the Oosterwijk et al. (2012). It is also possible that the observed size effect size of Oosterwijk et al. (2012) was an overestimation, which can lead to an underestimation of the number of participants needed for 80% power.

To address this, in Experiment 2 we attempted to replicate Oosterwijk et al.'s (2012) finding of a cost for switching between internal and external focus, at the same time as testing for effects of emotion switch. This design allowed us to investigate whether there could be a switch cost for emotional and cognitive sentences described from both internal and external focus. We investigated these three aims: 1) would there be a switch cost effect of emotional and cognitive sentences when they were described in external and 2) internal focus sentences, and 3) whether our procedure would be sensitive to the focus switch cost previously reported by Oosterwijk et al. (2012) by the means of conceptual replication. By doing so, we can investigate whether our failure to find switching effect was because there was no switching effect between emotional and cognitive sentences or that our experimental procedures are insensitive to switch costs, or whether the switch effect requires sentences that described external experience.

2.4 Experiment 2: Emotion switch cost and focus switch cost between emotion and cognitive sentences described internal and external perspective.

2.4.1 **Methods**

2.4.1.1 **Participants**

166 students participated in the study. 25 participants were below 80% accuracy. Therefore, only 141 were included in the final analysis (62 female, $Mean_{age}$ = 24.43, SD_{age}=3.89). Participants were recruited from two sources: one from undergraduate students from the University of Edinburgh, and from the online Testable. All participants were native English speaker – meaning that they reported being a native English speaker, speaking English before the age of 5 and were currently living in the United Kingdom. All participants were reimbursed with money or study credit for their participation. Informed consent in accordance with the Philosophy, Psychology Research ethics committee (PPLSREC) guidelines was obtained from each participant.

2.4.1.2 **Stimuli**

For our second experiment, we sought to investigate Oosterwijk et al. (2012) stimuli in more detail. We used all the stimuli that they used but modified the design for presenting these stimuli. Oosterwijk et al. (2012) did not specifically investigate the switching effect of emotional sentences. Instead, they changed the emotionality of the sentences to eliminate the priming effect of the sentences. In our current design, we instead manipulated whether the emotionality of each sentence pair was the same or different, as in Experiment 1. We refer to this as the emotion-switching manipulation.

Following Oosterwijk et al. (2012) we also manipulated whether the focus (internal/external) of each sentence was the same or different. We refer to this as the focus-switching manipulation. This allowed us to a) to test if we could replicate the Oosterwijk's focus switching effect and b) investigate a novel emotional switching effect for internal and external focus sentences. Thus, there were four general types of sentences in Experiment 2: External Emotion, Internal Non-Emotion, External Non-emotion, and Internal Emotion. **Table 7** shows some examples of these sentences. Note that in Oosterwijk et al. (2012), they used non-emotion as a category as they included sentences that refer to bodily state, referred as visceral sentences. In our current design, both cognitive and visceral were regarded as non-emotional sentences.

Table 7

Example sentences from each category, showing the combination of emotionality and focus.

	Emotional	Cognitive
Internal	*he loved his wife passionately*	*he was overcome by confusion*
External	*his face was pale with fear*	*he stroked his chin while thinking*

In Oosterwijk et al. (2012), there were 50 sentences in each category, totalling to 200 critical sentences. This was under the assumption that the sentences in a trial were always changing in the emotionality (i.e., there was no emotional prime prior to emotional target). For our design, we required both focus and emotionality to be switched in each trial so we could test the switching effect of emotionality and focus. To do that, we halved the 50 sentences in each category, resulting in 25 critical sentences to be used as prime sentences while the other half were used as target sentences.

In total, there were 100 prime sentences and 100 target sentences, effectively 100 sentence pair that changed in their emotionality and focus. As a counterbalance, half of the participants observed the prime sentences as target sentences and vice versa. This was done so that any switching effect was purely due to the sentence switching in different or same categories.

Participants saw one of 4 lists of possible prime-target pairs. Each target sentence was preceded by 4 different primes in these lists. These 4 different primes were rotated such that each target sentence was preceded by the four types of prime equally often. **Table 8** shows some examples of the prime-target pairs. Note that the target was always the same for every participant.

Table 8

List of prime and target sentences. EE = External Emotion, IN = Internal Non-Emotion, EN =External Non-emotion, and IE= Internal Emotion. Prime sentences are italicised and Target sentences are bolded.

	EN prime	IE prime	EE prime	IN prime
EE target	*She frowned when she was thinking* ***He narrowed his eyes in hate***	*Happiness gave him new energy* ***He narrowed his eyes in hate***	*He was pounding his fist on the table in anger* ***He narrowed his eyes in hate***	*The revelation hit her* ***He narrowed his eyes in hate***
IN target	He tapped his foot while wondering ***The remark puzzled him***	She was madly in love with him ***The remark puzzled him***	Her sad eyes were wet with tears ***The remark puzzled him***	His skin tingled while meditating ***The remark puzzled him***
EN target	*She meditated in the lotus position* ***She shook her head, not understanding***	*He was furious because of the argument* ***She shook her head, not understanding***	Contempt was showing on his face **She shook her head, not understanding**	She visualized the geometrical problem **She shook her head, not understanding**
IE target	He scratched his head in puzzlement **The distance between them made her sad**	She frowned with anger at the injustice **The distance between them made her sad**	Suddenly he knew the answer **The distance between them made her sad**	Pride made her lightheaded **The distance between them made her sad**

There were 320 filler sentences in total, organised into 160 pairs. The pairing was kept consistent with Oosterwijk et al., (2012). An example of a sensible filler sentence would be “he is sentenced with a mild boat”. For non-sensible sentences, one example would be “she came over to drink puzzlement”.

2.4.1.3 **Design**

The design for Experiment 2 was complex. The target sentences varied in both emotionality and focus. In addition, each target was preceded by four types of prime, which manipulate whether focus and emotionality were same or different. Overall, this gave a 2 (target focus: External vs. Internal) x 2 (target emotionality: Emotion vs. Non-emotion) x 2 (focus-switching: same vs switch) x 2 (emotion-switching: same vs switch) design.

The participants were asked to judge the sensibility as part of the sensibility judgment task. This was the same as Experiment 1.

2.4.1.4 **Procedure**

The procedure was the same as Experiment 1.

2.4.1.5 **Analysis**

We used similar model construction as described in Experiment 1, from maximal model to the best model that produced a converging result. However, we introduced new terms and conditions. There were two switching effect that we were interested in, the focus-switching effect (replicating Oosterwijk et al., 2012) and the emotion-switching effect (our main interest in these series of studies). In addition, we added a ‘focus’ term as a predictor to denote whether target sentences were internal or external in their focus. This was similar to the ‘emotionality’ term to describe target sentences that were either emotional or non-emotional. We started with omnibus model with all four factors and interactions. We then proceeded to explore the significant interactions with post-hoc models.

2.4.2 **Results**

Average reaction times (RT) and accuracies by their sentence type, emotionality and perspective can be seen in **Table 9**. Participants are all highly accurate in this task.

Table 9

Descriptive statistic by sentence type, Emotionality and Perspective of the sentences

Properties	Reaction time			Accuracy	
	n	*mean*	*sd*	*%*	*sd*
Sentence type					
prime	14100	1230	202	91	5
Target	14100	1195	204	94	4
Emotionality					
Emotion	14100	1196	205	94	4
Nonemotion	14100	1228	202	91	5
Perspective					
External	14100	1223	207	92	4
Internal	14100	1201	199	92	4

Figure 4 shows the average RT of correct external and internal focus sentences broken down by the focus-switching conditions. There is a pattern that people were slower in focus switch trials when it is external, but not when the sentences were described in internal focus. **Figures 5** shows the average RT in millisecond for correct cognitive and emotion sentences broken down by the emotion-switching condition. There is a pattern that people were slower in emotion switch trials when it is emotion sentences, but not when the non-emotional sentences.

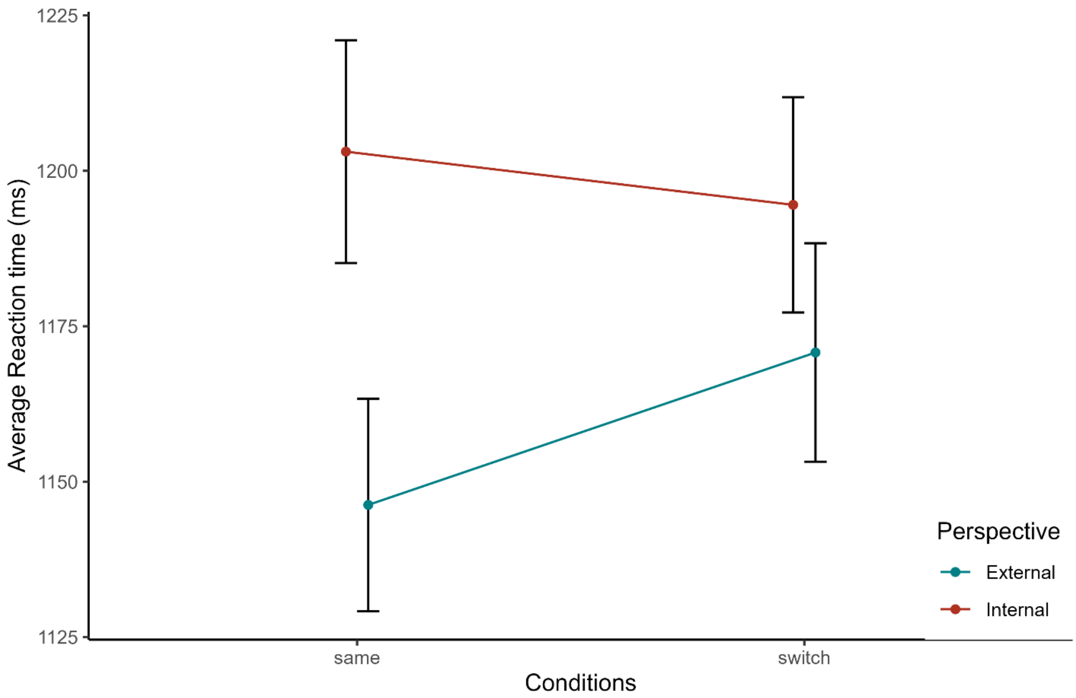

Figure 4 Plot of average reaction time between cognitive and emotion sentence broken down by focus-switching condition. The error bars represent standard error.

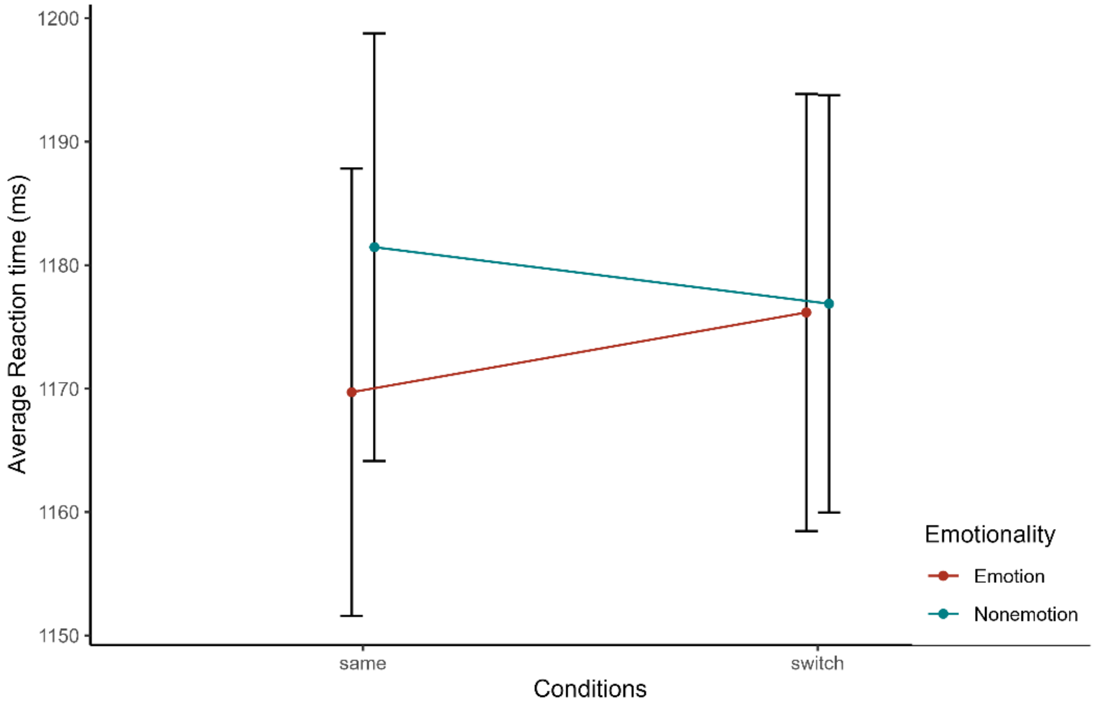

Figure 5 Plot of average reaction time between external and internal sentence broken down by the emotion-switching condition. The error bars represent standard error.

Table 10 shows the result of an omnibus model, investigating how the predictors influences participants' RT. There was no main effect of target emotionality.

This suggests that emotion and cognitive sentences were processed similarly and did not differ in their processing demands. We have found a main effect of focus, however, in that people are faster when processing internal focus sentences compared to external sentences. Specifically, people are 24 ms faster in responding to internal sentences compared to external sentences. This replicates the findings of Oosterwijk et al., (2012). We expected to see a focus-switching effect as seen in Oosterwijk et al. (2012), but there was no focus-switching effect nor any interactions with other factors. Furthermore, the effect of emotion-switching did not reach significances (p=0.076) but there were significant interactions.

Table 10

Summary of the mixed models for Experiment 2 for participants' RT

	Reaction Time			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	1183.49	19.71	1144.86 : 1222.12	**<0.001**
Focus-switching	2.50	2.26	-1.94 : 6.94	0.269
Emotion-switching	-4.53	2.55	-9.52 : 0.47	0.076
Target's emotionality	-6.38	10.55	-27.06 : 14.30	0.545
Target's focus	24.08	10.34	3.81 : 44.35	**0.020**
Focus-switching x Emotion-switching	0.79	2.33	-3.78 : 5.35	0.735
Focus-switching x Target's emotionality	-3.00	2.22	-7.35 : 1.34	0.176
Emotion-switching x Target's emotionality	-3.05	2.37	-7.71 : 1.60	0.198
Focus-switching x Target's focus	1.35	2.22	-3.00 : 5.70	0.543
Emotion-switching x Target's focus	-6.73	2.38	-11.39 : -2.06	**0.005**
Target's emotionality x Target's emotionality	3.84	10.34	-16.43 : 24.11	0.710

Focus-switching x Emotion-switching x target's emotionality	-0.26	2.22	-4.62 : 4.10	0.906
Focus-switching x Emotion-switching x target's focus	-0.82	2.22	-5.18 : 3.54	0.713
Focus-switching x Target's emotionality x Target's emotionality	1.11	2.21	-3.23 : 5.45	0.616
Emotion-switching x Target's emotionality x Target's emotionality	5.65	2.38	0.99 : 10.31	**0.017**
Focus-switching x Emotion-switching x target's emotionality x target's focus	-4.58	2.22	-8.94 : -0.21	**0.040**
Observations	12122			
Marginal R^2 / Conditional R^2	0.007 / 0.555			

Interestingly, when we look at the interaction of emotion switch and focus, we find a significant effect t(309.22) = -2.72, p < .01., indicating that the size of the emotion-switch effect varies between internal and external perspective of target sentences. We also find a three-way interaction of emotion-switching, emotionality and perspective t(604.05) = 2.44, p = 0.02.

To investigate these interactions further, we created 4 post-hoc models. Each model investigated the emotion-switching effect and its interaction with target's emotionality in a different subset of focus conditions. This allowed us to identify which type of focus that the emotional switching had an effect in. Our first model replicated Experiment 1, as it looked at the interaction between emotion-switching and target's emotionality in the subset of internal focus sentences. Our second model investigated the interaction between emotion-switching effect and target emotionality in the subset of external focus sentences. For completeness, with our third model we investigated whether there was any emotion-switch effect when the primes were internal, but the targets were external. Conversely, for our fourth model, we investigated emotion-switch when the primes were external, but targets were internal. This was to ensure that the emotion-switching effect we saw in each of these models were specific only to its focus. A summary of the models can be seen in **Table 11**.

Table 11

Post-Hoc models detailing the prime and target sentences, with their model's parameters. Bolded parameters were significant.

Model	Sentence type		Effect		
	Prime	*Target*	*Emotion-Switching*	*Target Emotionality*	*Interaction*
A - Replication of Experiment 1 using Oostwerwijk stimuli.	Internal	Internal	B = 5.740 (s.e. = 5.314) t = 1.080, p = 0.281.	B = -12.513 (s.e. = 14.924) t =-0.838, p = 0.404.	B = -3.111 (s.e. =5.502) t = -0.566, p = 0.572.
B – The effect of Model A with external sentences	External	External	**B= -11.791 (s.e. = 5.106) t = -2.309, p = 0.021.**	B = 0.162 (s.e. = 15.516) t = 0.010, p = 0.992.	B = -0.642 (s.e. =5.107) t = -0.126, p = 0.900.
C - Investigates whether there is any switching cost when the prime and target switched focus	Internal	External	B = -7.263 (s.e. =5.937) t = -1.346, p = 0.180.	B = 1.513 (s.e. = 15.836) t = 0.096, p = 0.924.	B = 4.232 (s.e. =5.044) t = 0.839, p = 0.402.
D - Investigates whether there is any switching cost when the prime and target switched focus	External	Internal	B = -0.719 (s.e. 5.430) t = -0.132, p = 0.895.	B = -2.262 (s.e. = 14.67) t = -0.154, p = 0.878.	**B = -14.424 (s.e. = 5.579) t = -2.585, p = 0.010.**

Only model B and D encountered significant effect. Specifically, we found that there is a main effect of emotion-switching in Model B. In Model B, external target sentences that have similar introspective state to their prime sentences (same condition), were processed on average 12 ms faster compared to trials that incur a switch in emotionality (switch condition). This is a novel result which suggests that people incur switch costs between emotional and non-emotional sentence when they are described using the external focus. In Model D, there is a significant interaction between emotion-switching and target's emotionality. This means that when the prime sentence was described in its external focus, but the target was internal, there was an interaction between the emotionality of the target and the emotion-switching effect. Further study needs to be conducted to investigate this unexpected interaction. **Figure 6** shows plot of emotion-switching conditions for each of the model described above.

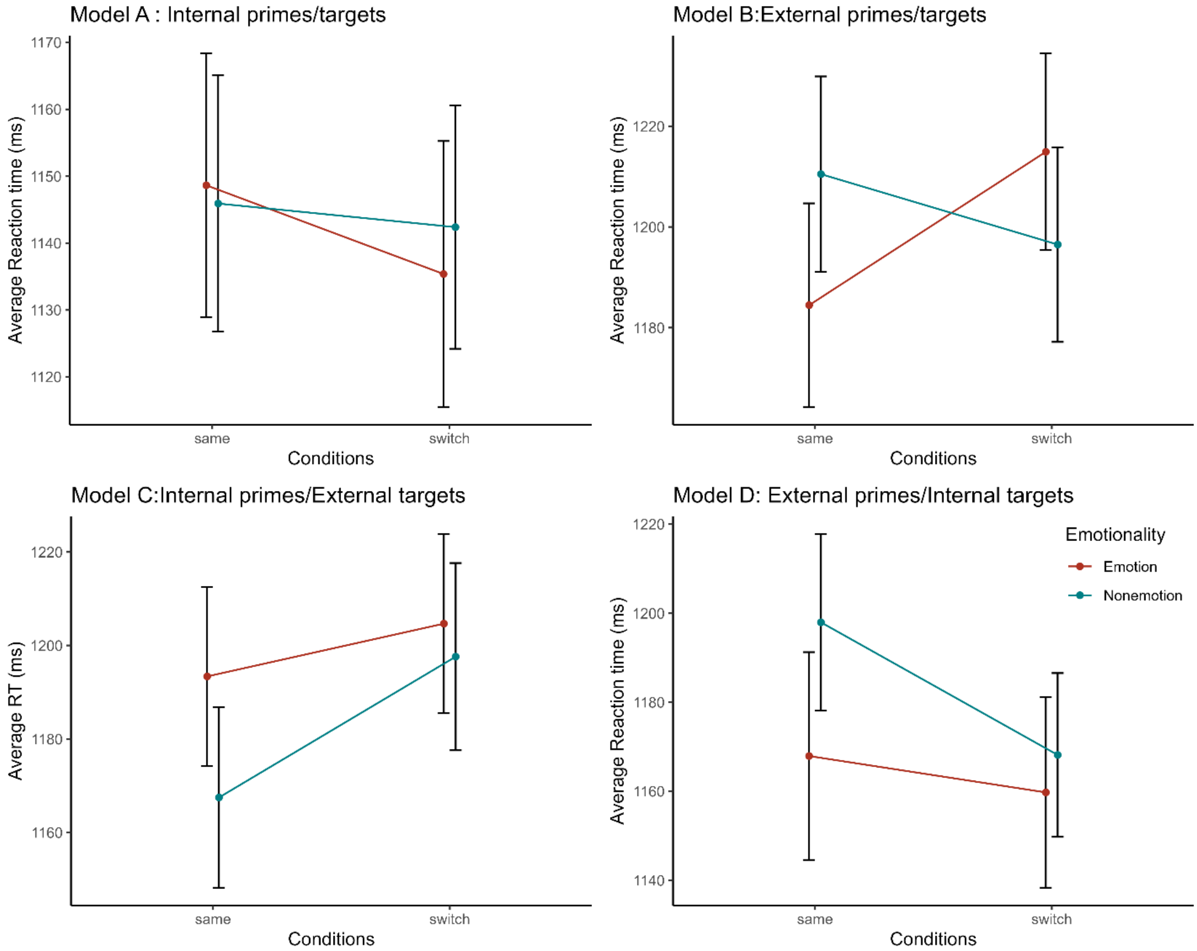

Figure 6 Plot of average reaction time in each of the post-hoc models. The error bars represent standard error.

Table 12 shows the result of an omnibus model, investigating how the predictors influences participants' accuracies. There is a main effect of emotionality. Specifically, when the sentences are emotional, there is an estimation of 0.22 increase in the log-odds of them being correct. There is an interaction between focus-switching and emotionality. That is, there is a 0.09 decrease in log-odds of them being correct in the trials where they have to verify sentence from the same focus, when the target is emotional.

Table 12

Summary of the mixed effect models for Experiment 2 for participants' accuracies

	Accuracy			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	3.26	0.11	3.05 : 3.47	**<0.001**
Focus-switching	0.03	0.05	-0.06 : 0.12	0.524
Emotion-switching	-0.05	0.05	-0.14 : 0.04	0.281
Target's emotionality	0.22	0.10	0.03 : 0.42	**0.023**
Target's focus	-0.10	0.10	-0.28 : 0.09	0.323
Focus-switching x Emotion-switching	-0.03	0.04	-0.12 : 0.06	0.489
Focus-switching x Target's emotionality	-0.09	0.04	-0.17 : -0.00	**0.043**
Emotion-switching x Target's emotionality	0.08	0.05	-0.01 : 0.17	0.089
Focus-switching x Target's focus	-0.03	0.04	-0.11 : 0.05	0.479
Emotion-switching x Target's focus	-0.07	0.04	-0.15 : 0.02	0.114
Target's emotionality x Target's emotionality	0.02	0.10	-0.17 : 0.21	0.815
Focus-switching x Emotion-switching x target's emotionality	0.00	0.04	-0.09 : 0.09	0.999
Focus-switching x Emotion-switching x target's focus	0.01	0.04	-0.07 : 0.09	0.828
Focus-switching x Target's emotionality x Target's emotionality	0.07	0.04	-0.01 : 0.15	0.099
Emotion-switching x Target's emotionality x Target's emotionality	-0.00	0.04	-0.09 : 0.08	0.950
Focus-switching x Emotion-switching x target's emotionality x target's focus	0.05	0.04	-0.03 : 0.13	0.202
Marginal R^2 / Conditional R^2	0.018 / 0.355			

2.4.3 **Discussion**

In experiment 2, we had three aims: 1) To test whether emotion-switching cost are present for external sentences, 2) to conduct a replication of Oosterwijk et al.'s (2012) finding of a focus-switching cost and 3) replicate our finding in Experiment 1. On the effect of focus, we replicated Oosterwijk et al.'s (2012) finding that people were generally faster to process internal than external sentences. However, we found no effects of focus-switching, nor any interactions with the other factors. Note that Oosterwijk et al.'s (2012) stimuli were all emotion-switch trials whereas ours were a mix of emotion-switch and emotion-same. But there was no suggestion in our data that a focus-switching effect was selectively present on the emotion-switch trials (i.e., no emotion-switch x focus-switch interaction).

On the effect of emotion-switch, no main effect was observed but we found a significant interaction with target's focus. We found a switch cost when both of the prime and target sentences described an experience from the external focus. Additionally, we did not find any emotion-switching effect in Model A, which replicates our failure to find an emotion switching effect of these sentences in Experiment 1.

Nonetheless, we found complex findings in this experiment. It was of interest to further elucidate this by conducting a study to investigate the emotional-switch effect on external focus sentences. As we found emotion switching effect in external sentences, this suggests that our procedure is sensitive to detecting switch costs but emotion-switching costs might only occur for external focused sentences. In Experiment 3, we attempt to replicate this finding by testing a larger set of external sentences, reverting to the design used in Experiment 1.

2.5 Experiment 3: Switching cost between emotion and cognitive sentences described from external perspective.

2.5.1 **Methods**

2.5.1.1 **Participants**

There were 141 participants, and 28 people did not pass the 80% accuracy threshold. In total, 113 participants (61 female; $Mean_{age}$ = 25.35, SD_{age}= 5.95) were included in the analysis. The participants were part of the prolific pool (https://www.prolific.co/). All were native English speakers with normal or corrected to normal vision and were reimbursed with course credit or money. Informed consent in accordance with the Philosophy, Psychology Research ethics committee (PPLSREC) guidelines was obtained from each participant.

2.5.1.2 **Stimuli**

We generated new external sentences based on Oosterwijk et al.'s (2012) stimuli. We used the same method of generating new sentences by starting with changing emotional sentences into cognitive sentences and vice versa. This was done to ensure that the syntax of both emotional and cognitive sentences remained similar and better controlled. To ensure that we had a similar number of sentences as Experiment 1, we started with 76 emotional and 76 cognitive sentences. Duplicating and changing the emotionality of these led us to twice the number of sentences, totalling to 304 critical sentences. Hence, we had 152 pairs of sentences. Filler sentences were kept as it were in Experiment 1, where there were 320 sentences which formed 160 pairs. **Table 13** shows some examples of the sentences.

Table 13

Shows the counterbalanced design such that each participant will observe the same target but have different prime sentences of the same condition. EE = prime and targets are emotions, CC = Prime and target are cognitive, EC = prime is emotion and cognitive is target, CE = prime is cognitive and emotion is target.

	List 1	List 2
Pair 1 Emotion target	His voice trembled with embarrassment **Her face was pale with fear.** *(EE)*	His voice trembled with uncertainty **Her face was pale with fear** *(CE)*
Pair 2 Cognitive target	His voice trembled with uncertainty **Her face was pale with confusion** *(CC)*	His voice trembled with embarrassment **Her face was pale with confusion**. *(EC)*
Pair 3 Cognitive target	He embraced his wife lovingly **She stopped, doubtful about where to go** *(EC)*	He thought about his wife while pacing **She stopped, doubtful about where to go** *(CC)*
Pair 4 Emotion target	He thought about his wife while pacing **She stopped, scared of where to go** *(CE)*	He embraced his wife lovingly . **She stopped, scared of where to go** *(EE)*

Similar to the Experiment 1, the sentences were pre-normed by participants that did not participate in the actual study. We conducted two norming studies. The first one was similar to the norming in Experiment 1, whereas the participants were asked to judge the emotionality of the sentences. 18 participants ($Mean_{age}$ 18.95, 17 females) participated in this study. Our final set of stimuli were significantly different in their emotionality, and emotional sentences were rated higher (mean=4.13, s.d =1.03) than cognitive sentences (mean=1.53, s.d =0.50) [t(867) = 55.60, p <0.001].

Additionally, we also conducted a separated study to norm the focus of the sentences – asking the participants to rate whether the sentences were highly internal (1) or highly external (7) on a Likert scale. 19 Participants (Mean¬age 19.67, 6 males) participated in this study. We found that the external sentences (mean=3.68, s.d =0.94) differed significantly from internal sentences (mean=1.53, s.d =0.50) [t(914) = 49.55, p <0.001]. No sentences were removed in this experiment.

2.5.1.3 **Design**

Experiment 3 used the same design as Experiment 1 but instead of sentences that described experiences from an internal focus, we used sentences that described them from an external focus.

2.5.1.4 **Procedure**

Experiment 3 used the same procedure as Experiment 1.

2.5.1.5 **Analysis**

Our analysis was the same as Experiment 1. The reaction times were winsorised to 2 standard deviations above and below the mean. We used mixed models with emotion-switch and target's emotionality as the fixed terms. For our random effect, we allowed the intercepts and slope of interaction between emotion-switch and emotionality to vary by participants, and intercept and slope of emotion-switch to vary by sentences. Mixed logistic model was used to investigate participants' accuracy using the same model structure as the reaction time.

2.5.2 **Results**

Average reaction times (RT) and accuracies of prime sentences and target sentences can be seen in **Table 14**. **Figure 7** shows the average RT in millisecond for cognitive and emotion sentences broken down by their sentence types with error bars representing standard deviation. Participants have similar RTs for prime and target sentences and are all highly accurate.

Table 14

Summary of descriptive statistics by the sentence type

Sentence type	Reaction time			Accuracy	
	n	*mean*	*sd*	*%*	*sd*
Prime	16498	1339	374	93	26
Target	16498	1339	381	93	26

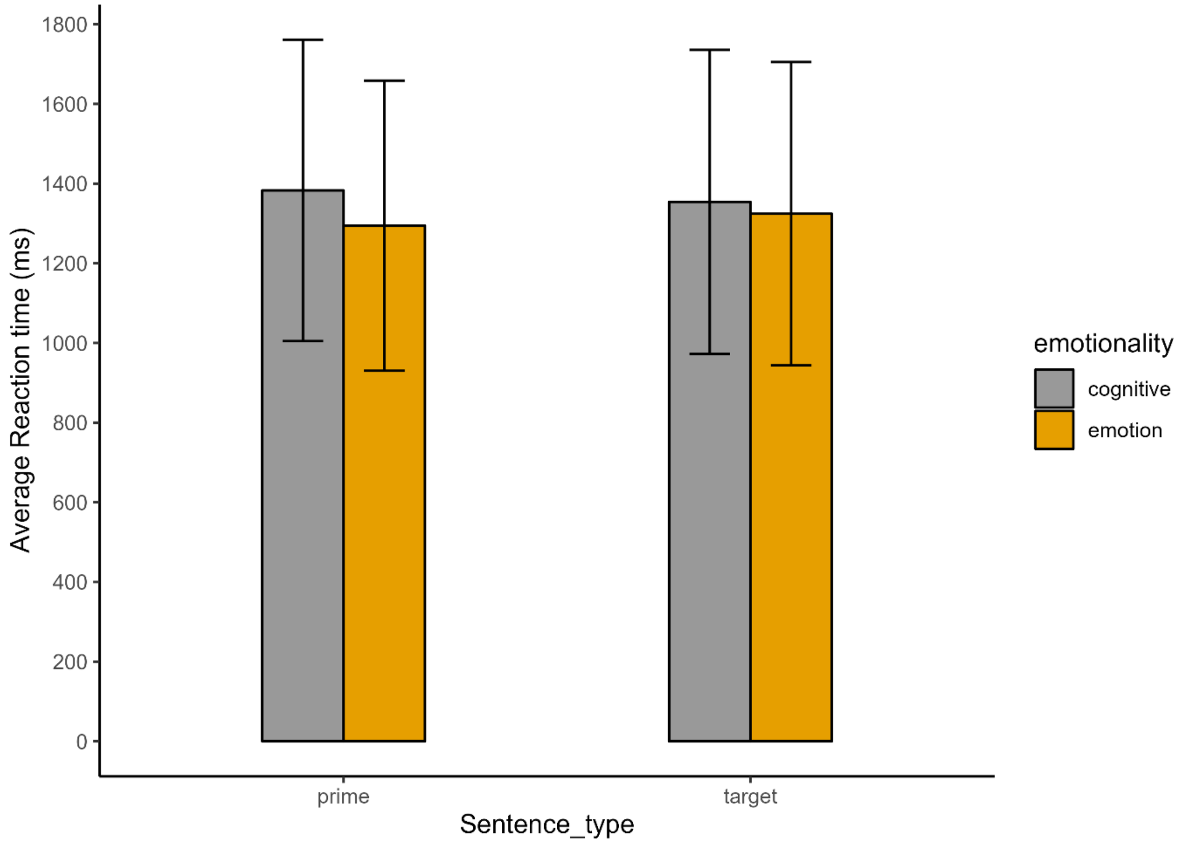

Figure 7 Plot of average reaction time between cognitive and emotion sentence broken down by the sentence type. The error bars represent standard deviation.

Table 15 shows the RTs and accuracies for each emotionality of target sentences. In general, participants showed faster response time in verifying emotion sentences than cognitive sentences [t(16497) = 18.23, p < .001].

Table 15

Summary of descriptive statistics by the emotionality of the sentences

Emotionality	Reaction time			Accuracy	
	n	*mean*	*sd*	*%*	*sd*
Cognitive	16498	1369	389	92	26
Emotion	16498	1309	383	94	25

Figure 8 shows the average reaction time of the switching effect broken down by the emotionality of the target sentences in correct trials only (where responses to

both prime and target sentences were correct). Unlike Experiment 2, RTs appear to be similar in both switching conditions.

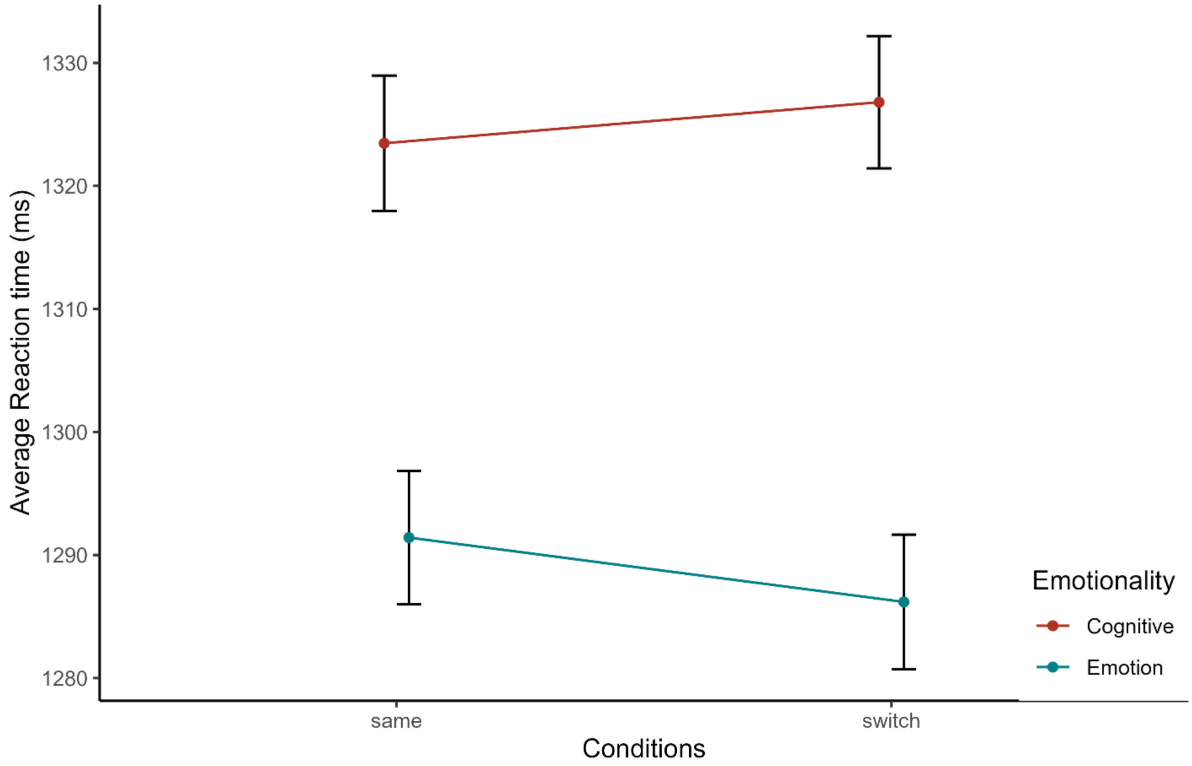

Figure 8 Line graph showing the average reaction time between the two conditions (same and switch) and the emotionality. Error bars represent standard error of the mean.

Table 16 shows the model parameters for participants RT and **Table 17** shows the model parameters for participants' accuracies. Both the main effects of emotionality and switching were not significant. The interaction was also not significant.

Table 4

Summary of the reaction times examining the effects switching and target's emotionality

	Reaction Time			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	1324.20	24.77	1275.65 : 1372.75	**<0.001**
Switching	-0.73	2.74	-6.11 : 4.64	0.790
Emotionality	18.40	15.92	-12.81 : 49.61	0.248
Switching * Emotionality	-1.76	2.34	-6.34 : 2.83	0.453

Observations	14248
Marginal R^2 / Conditional R^2	0.003 / 0.570

Table 5

Summary of accuracies of the mixed models examining the effects switching and target's emotionality

	Accuracy			
Predictors	*Estimates*	*std. Error*	*CI [lower : upper]*	*p*
(Intercept)	3.13	0.12	2.89 : 3.37	**<0.001**
Emotionality	0.03	0.11	-0.19 : 0.25	0.776
Switching	-0.02	0.03	-0.08 : 0.05	0.552
Switching * Emotionality	0.02	0.03	-0.04 : 0.09	0.464
Marginal R^2 / Conditional R^2	0.000 / 0.348			

2.5.3 **Discussion**

This experiment used the same procedure and design from Experiment 1 but focussing on sentences that were describing emotional and cognitive events from an external focus. Although in Experiment 2 where we did find a switch cost effect in external sentences, we did not replicate that result in this experiment. In Experiment 3, we found no emotion-switch effect using a larger set of sentences with more external sentences per participants which we argued to be able to show more reliable result. This suggests that the effect in Experiment 2 may have been a false positive.

2.6 **General discussion**

In this study, we investigated whether there was a modality switching effect between emotional and cognitive sentences. In Experiment 1, we observed no switch cost effect after the introspective sentences changed in their emotionality. We then replicated Oosterwijk et al. (2012)'s experiment using our own procedure in Experiment 2. We reproduced our null result in Experiment 1, however, there was a switching effect observed in some part of the data that suggested that emotion switching cost may be observed in external focus sentences. However, our third experiment failed to replicate this effect, showing that there was no switching cost in sentences that were described in the external focus sentences. Taken together, our series of experiments do not provide evidence that that participants did not process emotional and cognitive sentences differently. The null results mean that we do not have enough evidence to determine whether different types of introspective sentences, upon comprehension, simulate different processing modalities.

Our result is compatible with weak embodiment theories. This account suggests that representation of concepts does not solely rely on activation of primary sensorimotor or interoceptive representations but works in tandem with single or multiple convergence zones that represent knowledge amodally (e.g., Patterson et al., 2008; Vigliocco et al., 2004). Our data suggests that no costs occur when switching between emotional and cognitive sentences. This would mean that processing valence is not entirely dependent on the automatic activation of the affective representations as previously found elsewhere (Cardona et al., 2014; Gallese et al., 2004). This means that sensorimotor and affective regions do not automatically activate following any retrieval and processing of emotional concepts. This suggests that abstract concepts involve the simulation beyond sensorimotor experience – complimenting the weak embodied theory. Our concern in this experiment is not to support any of the position in the embodiment literature, rather, our data are simply compatible with weaker embodiment theories concerning processing of introspective states.

Conversely, our data does not support the strong embodied theories. Strong embodiment account outlined the complete dependency of representation to include activation of sensorimotor and affective regions. For example, various studies showed that sentence processing can be facilitated with congruent body movement. Glenberg and Kaschak (2002) showed participants two type of sentences that either have movement implied towards the body ("Open the drawer") or away from the body ("Close the drawer"). To emulate movement away/towards the body, they provided the participants with an answer box with 3 buttons arranged perpendicular to their body with the middle button being the neutral option. Their finger would rest there between the trials. The participants had to press a button nearer or farther away from them, which resulted in the movement of hands inwards or outwards from the body. They found that participants were faster in judging sentences that described movement away from the body, when they had to move their hands away from the body and vice versa. Similar result could be seen in Zwaan and Taylor (2006)'s study, where participants had to rotate a knob clockwise to advance a segment of a sentence to continue the story. Sentences that implied clockwise rotation were read faster compared to when there was a mismatch. Taken together, these two studies showed a strong relationship between sentence comprehension and action-perception and underscores the automaticity of embodiment of concepts.

However, more recent studies with very large samples have failed to replicate Glenberg and Kaschak (2002) and Zwaan and Taylor (2006)'s findings (Morey et al., 2022) and there is evidence of publication bias in this literature (Winter et al., 2022). Our findings are in agreement with these recent findings in suggesting that simulation does not occur automatically when people make sensibility judgements to simple sentences.

Various studies reported the importance of context in studying emotion. Niedenthal et al. (2009) showed that emotion-focused processing (e.g., identifying the referents of the concept words) shows electromyographic (EMG) activations (facial muscle defining smile or frown) but when it was a perceptual-focused task (e.g., identifying the capitalisation of the concepts words), they did not find any facial EMG evidence of emotional stimulation. Other evidence of the importance of task in demonstrating emotion-specific results could be seen in De Houwer et al. (2001) study. They found that the Affective Simon effect was not present when the instruction asked the participants to classify various valenced images (e.g., chocolate) on their perceptual properties (e.g., manmade or natural) compared to when they asked the participants to classify them by their valence (e.g., positive or negative). Additionally, Havas et al. (2007) argued that the emotional simulation can be obtained from sentences too (e.g., You and your lover embrace after a long separation). They asked participants to hold a pen on their teeth (mimicking smiling) or using their lips (mimicking frowning) while rating whether the sentences were pleasant or unpleasant. They found that people were faster in judging pleasant sentences when they were 'smiling' compared to frowning and vice versa. However, while the participants were unaware of the reason of the valence manipulation, the actual task involved classifying the valence of the sentence which could be taken as processing it. This has been replicated in various other studies the looked at fine-grained facial changes that were also detected by EMG and ERP (Davis et al., 2017; Oberman et al., 2007). Taken together, these studies show that instruction or tasks are important to elicit emotion-specific behaviour. After all, most embodiment studies showed embodied effect as a function of context (Winkielman et al., 2018). We did not have any instructions that requires them to judge the emotionality of the sentences, instead we asked them to judge the plausibility of the sentences which is a semantically focused task. Therefore, it is possible that participants were not focused on valence of the sentences in our study.

There is also a possibility that participants did not process the sentences at a deeper level. This means that people did not perform adequate simulation of emotional and cognitive sentences. Previously, modality-switching studies (e.g., Pecher et al., 2003; Vermeulen et al., 2007) have tended to use a property verification tasks (e.g., Hald et al., 2011) instead of sensibility judgment task. In Vermeulen et al., (2007), for example, they found modality switching effect in their object verification task. They compared reaction time to verify affective sentences (e.g., 'VICTIM can be stricken') preceded by other sentences describing affective properties (e.g., ORPHAN can be hopeless) or sentences describing perceptual properties (e.g., 'VICTORY can be sung'). Verifying different modalities (stricken vs. sung) were slower compared to the same modality (stricken vs. hopeless), which they interpreted as a switching effect between perceptual and affective modalities. We could not be certain whether the same depth of processing occurred in our design which asked the participants to judge the sensibility of the sentences. Moreover, in our experiments, people were around 400-500 ms faster to respond to the task than in the Oosterwijk et al.'s, (2012) study. This may indicate that our participants processed the sentences at a shallower level compared to the previous study using the same task.

There are number of ways to change the procedure to increase the likelihood of simulations (and therefore the switching costs). Future studies could instruct participants to process the sentences slower and more deeply to encourage elaborate simulation as it has been shown deeper processing may involve more elaborate simulations (e.g., Abassi et al., 2015). A different option is to use different tasks such as property verification or valence judgement tasks. Another possibility can also be to use first-person ("I") instead of third-person perspectives (e.g., "the boy", "the girl"). It has been shown that there is a greater emotional engagement of emotional sentences when it is presented in a way that relates to their own experiences (Wallace-Hadrill et al., 2016; Child et al., 2020). Moreover, there is evidence that shows personal pronouns may elicit greater engagement of physiological behaviour of emotions (Weis & Herbert, 2017). There is also evidence that highly emotive paragraph could activate affective regions when the reader was asked to vividly imagine the scenes and personally involved in them by the usage of the word “you” (Wilson-Mendenhall et al., 2013). Future study could investigate whether changing the perspective would result in greater engagement and hence a possible switch cost effect. Regardless, an advantage of our design is that the sentences are more naturalistic compared to a property verification task and therefore underscoring the possible automaticity of embodiment during sentence comprehension. Our result shows that is not the case.

Our result is not compatible with Oosterwijk et al., (2012) As we did not replicate the focus switching effect of internal and external sentences in Experiment 2 of our study. The failure to observe the focus-switching effect may be due to our design. We used a different design that allowed both emotionality (emotion and cognitive) and focus (internal and external) to be investigated simultaneously. This means that our design may not be sensitive to show the focus switching effect. However, we did use the same sample size and number of trials as their study. In fact, we also found the main effect of perspective, in that, people were faster in processing internal sentences compared to external sentences in general. This suggests that our participants processing the sentences similarly to theirs. However, our participants RTs are considerably faster compared to Oosterwijk et al. (2012) in general. Perhaps this shows that these small switching effects are highly sensitive to the precise experimental parameters and the way in which participants approach the task, which may include the possible unknown confounds of conducting this experimental procedure online.

To conclude, in three experiments, we investigated whether there were switch cost effect between sentences that describe interoceptive experience but varied in their valence. We did not find reliable evidence for a switch cost effect between emotional and cognitive sentences, suggesting that they are governed by similar semantic processes. Our investigation on the difference between processing within the introspective modality itself is novel and contributes the growing understanding of interoception as another distinct dimension alongside the five primary senses (Collen et al, 2017). But as far as our data goes, it suggests that the modality which governs the processing of emotional and cognitive sentences could be similar.

Chapter 3: The interfering emotions: Using Cumulative Semantic Interference Paradigm to investigate the semantic categorisation of emotional concepts.

3.1 **Abstract**

It has been shown that our semantic system has a strong category-based organisation for object concepts. We group objects to form coherent categories based on their appearance, functions and other sensory-motor characteristics (e.g., birds, vehicles, instruments). Recent embodied cognition theories have also highlighted the importance of emotion (in particular, valence) in semantic representation, especially for abstract words. Here, we used the Cumulative Semantic Interference (CSI) paradigm to investigate whether emotional properties are an important organising principle within the semantic system. The CSI effect is well documented in other studies that investigated non-emotional semantic categories, such as birds, vehicles, and instruments. In our study, we investigated CSI effects for set of items that share emotional connotations, either when the emotion is directly labelled (emotion label; e.g., happiness) or not (emotion-laden; e.g., graveyard). In our first experiment, we showed that as people name emotion from facial expressions in a blocked-cyclic presentation, their naming latencies become slower as they retrieve emotion labels repeatedly. This shows that emotion labels form a coherent category and are susceptible to interference. In Experiment 2, we did not find a CSI effect when people name emotion-laden pictures that were grouped by their valence. This suggests that processing concepts of similar valence does not cause interference, suggesting that emotional association through valence may not be an important part of how we identify and represent objects. Taken together, our results suggest that emotion has a stronger effect on lexical-semantic processing when direct emotion labels are accessed but not for emotion-laden concepts.

3.2 **Introduction**

Object concepts have a strong category-based organisation. For example, a chair, table and drawers can be categorised as furniture, whereas apple, lemon and orange can be categorised as fruits. These object concepts are grouped together as they have similar externally experienced features such as their function, appearances and other sensory-motor characteristics (Cree & McRae, 2003). Less is known about how internal experiences, like emotions, contribute to semantic organisation. Recent research has outlined the role of emotions in semantic representation of abstract objects (Vigliocco, et al., 2009; Crutch et al, 2013; Binder, 2016). Less is understood whether these affective characteristics are part of the organising principle for semantic representation of concrete concepts. To put it simply, do we represent objects as being similar to one another, simply because they elicit similar emotions from us? We explore these questions using two experiments in this paper where we use Cumulative Semantic Interference (CSI) to probe whether interference occurs between emotion concepts and whether objects of similar valence interfere with one another in picture naming task.

Emotion-related concepts can be described in various ways, but a lot of focus has been on distinguishing between categories within the emotional domain (Barrett et al., 2018; Siegel et al., 2018). They can also be distinguished in two ways: either describing the emotion itself or as describing concepts with emotional connotations (Pavlenko, 2008). These are referred to respectively as emotion label words such as happy and sad, and emotion-laden words such as cemetery and birthday. Another important thing to note is how emotion-laden concepts are concepts that have emotional properties or can be rated on the degree of valence and arousal (Russell, 1980; Lang & Bradley, 2007). For example, emotion-laden words are concrete words that have a degree of valence and arousal. For example, a graveyard would usually be rated as having low ratings in valence, implying that it is concept with negative connotation (Kurdi et al., 2017). This suggests that representing object concepts can include representing valence information.

Studies tend to mix these two types of words together in various affective task such as emotional Stroop task (Ben-Haim et al., 2016; Williams, Mathews & MacLead, 1996), lexical decision tasks (Chen et al., 2015; Scott et al., 2014) and even affective

Simon task (De Houwer et al., 2001; De Houwer et al., 2003). However, there are also studies that investigate the distinction between the two class of emotion words. For example, Zhang and colleagues report a clear distinction between these two classes of emotion words as they have different neural correlates (e.g., Zhang et al., 2017; Zhang et al., 2019; Wu et al., 2021). There is also a larger affective Simon task effect for emotion label words compared to emotion-laden words (Altarriba & Basnight-Brown, 2011). Taken together, this suggests that emotion labels and emotion-laden words are different and should be controlled for in studies investigating emotional processing in words. We will next review how affect is thought to contribute to the understanding of emotion labels and emotion-laden concepts.

How emotion labels are represented remains an area of debate. Various definitions and hence, operationalisations of emotion have been proposed in the literature, but no consensus has been reached regarding how we identify and understand our own emotions and those of others (Izard, 2010). This in turn poses a problem in how we can classify what emotions are or how they are organised. Researchers have argued that we use our body to identify and classify our emotions (Damasio, 1999, Ekman, 1984; Anderson & Adolphs, 2014). This means that changes of activity in automatic nervous system can be patterns for specific emotions. The language used to define these bodily changes is important as it has been argued that language scaffolds our knowledge of emotions (Barrett, 2006; 2016). This means that we make sense of our biological markers with verbal labels. For example, we might label the experience of increased heart rate, gastrointestinal activities, and withdrawal behaviours as being in a state of fear (LeDoux, 2003; Simić, et al., 2021). The language used to define specific emotions can be said to be categorical and distinct (e.g., fear and happy are two distinct emotions). Indeed, Ekman (1992) has argued that there were 6 different emotions that are semantically distinct from one another. They have asked populations with no exposure to English to identify pictures of specific facial expressions (Keltner & Ekman, 2000). A diverse set of populations could identify 6 distinct emotional expressions, which led to their claim of 6 universal basic emotions. The original basic set has been expanded to include more types of emotions (e.g., Plutchik, 2001) but the idea that emotions concepts are categorically distinct, termed the categorical approach by Panksep, (1998), serves as the foundation for many studies in emotion recognition (e.g., Matsuda et al., 2013; Fujimura et al., 2012), and in computational modelling of emotion-cognition interface used to detect affective disorders (see Hudlicka, 2017 for reviews).

Another view holds that emotion concepts could exist in a continuous space as opposed to discrete concepts. Russell (1980) posited that emotional stimuli can be defined in terms of their degree of valence (the degree of pleasantness) and arousal (whether a concept invokes arousal). This operationalism is often useful for studies on emotion-laden concepts as well as emotion labels. This is called the dimension approach (Barrett, 1998). Therefore, emotion labels are distinguished on this view by the degree to which they differ on the underlying affective dimensions – so happy and sad are distinct because they differ a lot on valence. Whether the organisation of emotion concepts is continuous or discrete, it is likely that emotion labels form a coherent category in the semantic system that is distinct from other types of concepts. In the present study, we investigated this by testing whether emotion labels interfere with one another when people are required to name emotional states rapidly and repeatedly.

In categorising object concepts, various claims have been made. Various studies have postulated that sensorimotor characteristics are central to how object categories are organised. For example, Farah and McClelland (1991) provided a parallel distributed processing model of semantic memory for living and non-living things. In a series of experiments, they found that when visual semantic units were damaged, impairments of knowledge of living things were observed. Conversely, impairments of non-living things were observed when the functional semantic units were lesioned. They argued that sensory information is important for identifying living things while functional properties of an object are more important for non-living objects. In another study, Dilkina and Lambon Ralph (2012) used a data driven approach to investigate the conceptual structures of object knowledge in four feature types: perceptual, functional, encyclopaedic and verbal. They found that items from the same category tended to share features of all four types. However, perceptual features best predicted general taxonomic categories, highlighting the role of perceptual similarity in categorising objects.

Further studies have noted the importance of other modalities such as linguistic and emotional information in semantic processing (Kousta et al., 2009; Newcombe et al., 2012; Xue et al., 2015). It has been suggested that, particularly in regard to abstract concepts, the role of affective or emotional grounding is important (Vigliocco, et al., 2009; Crutch et al, 2012; Binder et al., 2015). Researchers have argued that emotional properties (e.g., valence, arousal) are important in representing intangible concepts such as truth or democracy, as they have no clear sensorimotor or functional referents in the world. Further, a study by Newcombe et al. (2012) has shown that the dimension of emotion experience– which is defined as the easiness of representing emotional experience – was associated with faster and more accurate categorisation of abstract words compared to concrete words. Furthermore, most studies that investigate categorisations of emotions either focused on the biological components of emotions (e.g., Barrett 2017; Lindquist, 2021 for review) or used abstract concepts to investigate emotional concepts (Kousta et al., 2011; Vigliocco et al., 2014). Regardless, these studies support the importance of emotional grounding of valence especially in abstract concepts.

The above-mentioned studies suggest that emotional information contributes to the representation of abstract concepts but is less important for object semantics (as these are more informed by sensorimotor properties). However, a recent study has called this into question. Winter (2022) investigated whether emotional grounding affected only abstract concepts and not concrete objects. They used ratings from various languages other than English and found that emotional grounding was only relevant to a small set of abstract concepts. In fact, they found that emotional grounding (defined as how valence or arousal are activated when representing concepts) was often true for concrete concepts as well as abstract concepts and, under some circumstances, concrete concepts are more strongly associated with emotional experience than abstract ones. In another strand, a norming study on 14000 English words showed that valence and arousal were, on average, higher for words strongly associated with sensory experience (Warriner et al., 2013). Therefore, it can be argued that emotional information could also be activated in processing concrete object concepts. These recent findings suggest that emotional experiences may be more central to knowledge for concrete concepts than has previously been assumed. This opens the possibility that emotional properties like valence may contribute to the structure and organisation of object concepts.

In the present study, we investigated this by testing whether objects that share similar valence (but are otherwise unrelated) interfere with one another when people are asked to name them rapidly and repeatedly. To do this, we used the cumulative semantic interference (CSI) paradigm, outlined next.

The CSI paradigm can address this question is by investigating whether object concepts are categorised by their emotional properties (Belke & Stielow, 2013; Schnur et al. 2006). The basic phenomenon is that inteference builds up when people name a set of semantically related objects repeatedly. The interference manifests as increases in naming latencies. CSI effects are thought to depend on semantic relationships between concepts (Howard et al., 2006; Oppenheim et al., 2010). Therefore, by testing whether CSI occurs among emotional items, we can probe the role of emotions in the semantic organisation of concepts.

There are two ways to present the stimuli in this paradigm: in a form of continuous presentation or blocked-cyclic presentation. In continuous presentation, people name a series of pictures of items from a single category, interspersed with items from other categories. The CSI effect can be observed as a linear increase of RTs as people go through the unique presentation of items (Howard et al., 2006). CSI studies using continuous presentation have observed a cumulative slowing in naming latencies as a function of the number of same-category items the participant has previously named. For example, in naming a series of pictures of; CAT, TRAIN, DOG, TRUMPET, GUITAR, GOAT, the reaction time to correctly name DOG after previously naming CAT will increase. The reaction time for naming GOAT will be slower than the reaction time for naming DOG. This cumulative slowness of reaction time is the main effect of CSI.

In the blocked-cyclic approach, each block contains a small number of different concepts (often 4) and these are presented repeatedly over a number cycle (e.g., CAT, DOG, HORSE, GOAT, DOG, GOAT, CAT, HORSE…). Naming items from a list of repeated items from the same semantic category (homogenous or related context) takes longer than naming items from a mixed list with items taken from multiple semantic category (heterogenous or unrelated context). This effect tends to be present from the second cycle onwards (Belke & Stielow, 2013). As related and unrelated blocks contain the same number of items and amount of item repetition, slower responding in related blocks is attributed to competition arising between the semantically related items (Belke, 2017). The blocked-cyclic paradigm has been extensively in studies of aphasia to identify patients with ‘refractory access deficits’ (e.g., McCarthy & Kartsounis, 2000, Wilshire & McCarthy, 2002; Schnur et al. 2006).

There are a number of accounts of the precise mechanism of the CSI effect (Damian et al., 2001; Belke & Stielow, 2013; Howard et al., 2006; Oppenheim et al., 2010). These generally focus on spread of activation between semantic representation (de Zubicaray et al., 2015; Caramazza, 1997) and the degree of semantic feature overlap between concepts (Navarrete et al., 2012). Additionally, theorist also proposed an incremental competitive learning to explain the mechanism of CSI without depending on lexical competition between the target items and competitors (Damian et al., 2005; Howard et al., 2006). Regardless, while some researchers have argued that different mechanisms underpin the continuous and blocked-cyclic paradigms (Riley, McMahon & de Zubicaray, 2015), a recent computational model has demonstrated that effects in both paradigms can be explained by the same effects of semantic relatedness (Roelofs, 2018).

CSI studies have shown that interference can arise from various types of semantic relationship. For example, whether objects are grouped together by their association (e.g., dog and bone) or by category (e.g., dog and cat), they have shown a CSI effect in the continuous presentation paradigm (Rose & Abdel Rahman, 2017). A study on aphasic patients has found that interference occurs when naming geographical locations (Crutch & Warrington, 2010). Specifically, they found greater interference when patients named a set of places that are close together geographically compared with naming places that are far away from each other. They suggested that places closer together are represented as more semantically similar to one another and therefore interfered more. Additionally, another study in stroke aphasic patients has also suggested that concrete concepts interfere with each other when they share perceptually similar features, but abstract concepts interfered when they shared similar associative characteristics (Crutch & Warrington, 2010). Thus, while CSI effects have been demonstrated most commonly among categorically related sets of concrete objects (see Roelofs, 2018 for review) there is some evidence that similar effects arise for other types of semantic relationship. However, no previous studies have investigated whether items interfere with each other when they share similar emotional properties.

In the present study, we investigated the circumstances under which emotion-related concepts interfere with one another. In Experiment 1, we tested emotion concepts that were annotated with a direct label (e.g., happy, sad, shocked) and whether they show a CSI effect, similar to that seen for object concepts. To elicit emotion labels, we used facial expressions obtained from Radboud Face database (Langner et al., 2010). We used the blocked-cyclic method as this method requires fewer concepts as stimuli. This is important as there is a limited number of emotion labels (Ekman, 1984). We tested whether emotion label descriptions can interfere with one another when they were blocked together, hence showing a CSI effect. This is important as interference for more abstract concepts is rarely investigated.

Having shown in Experiment 1 that emotion labels interfere with each other, in Experiment 2, we tested whether emotion-laden objects with similar valence also interfere with one another. Using a similar blocked-cyclic design as Experiment 1, we grouped positive and negatively valenced concepts together (e.g., rainbow, puppy, fireworks, penguins). Importantly, these objects do not refer to the direct emotion labels. If emotion-laden objects show a robust CSI effect when grouped by valence, this would provide evidence that emotional associations are automatically activated when we process object concepts, irrespective of whether the actual name of an emotion is being invoked. This would suggest that affective information such as valence play a role in the process of lexical-semantic access, suggesting that they are an important part of the core representation of objects.

As we carried out these experiments online (due to the covid-19 pandemic) participants provided written or type responses rather than spoken responses. One study has demonstrated a strong CSI effect when they used typed response rather than the usual spoken response (Stark et al., 2023). They compared both typed and spoken responses in the continuous naming paradigm and have showed similar findings regardless of the modality of the response. This is an important development as typed responses are a better fit for online experiments as differences of audio systems may result in confounds in recording language production. Not to mention arduous technical settings are needed to ensure similarity across different participants’ computers (Vogt et al., 2021). As our particular study will be done during the time where physical interaction is not available, the options to conduct this particular study using typed response is useful. As we used the block-cyclic paradigm, our study provides an opportunity to replicate and extend Stark et al.'s (2023) findings, by investigating whether CSI effects are detectable with typed responses in blocked-cyclic as well as continuous naming paradigms.

3.3 Experiment 1 – Cumulative Semantic Interference when Naming Facial Expressions vs. neutral objects.

This experiment was pre-registered; the pre-registration can be obtained from this link https://osf.io/9xqw5.

3.3.1 **Methods**

3.3.1.1 **Participants**

We calculated a prospective power analysis to identify the number of participants that needed to be recruited. As there were no direct experiments that can be used to inform the current design, we decided to use Harvey and Schnur (2015)'s effect size as we used their blocked-cyclic design. Although Harvey and Schnur used spoken names, typed data seemed to give similar cumulative interference effect as highlighted by Stark et al., (2023). To be sensitive to their small effect size of d=0.37, at 0.80 power, we needed 80 participants.

81 participants ($Mean_{age}$ = 27.8, SD_{age} = 4.4; 59.3% women) participated in the study. All 81 participants achieved above 80% accuracy and were included in the final analysis. Participants were recruited from the online Prolific participant pools. All participants reported being a native English speaker, speaking English before the age of 5 and were currently living in the United Kingdom. All participants were reimbursed with money for their participation. Informed consent in accordance with the Philosophy, Psychology and Language Science Research ethics committee (PPLSREC) guidelines was obtained from each participant.

3.3.1.2 **Stimuli**

Our stimuli formed 4 categories: emotion labels, and 3 neutral object categories. To best represent emotion label concepts, we used facial expressions. Neutral pictures were obtained from the Bank of Standardized Stimuli (BOSS; Brodeur et al., 2010) and emotion label pictures were obtained from the Radboud Faces Database (Langner et al., 2010). They were all coloured pictures and were scaled consistently throughout the experiment.

In BOSS database, we chose 3 object categories which was also used by Harvey & Schnur (2015). These categories were vehicles, musical instruments, and birds. **Table 1** shows the properties of the pictures that we chose.

Table 6

Selected objects and their relevant properties obtained from BOSS (Brodeur et al., 2014)

Modal category	Modal name	Name Agreement	Category Agreement	Familiarity		Visual complexity	
		%	*%*	*mean*	*sd*	*mean*	*sd*
Bird	Peacock	98	97	4.19	1.17	3.64	1.41
	Eagle	67	100	4.33	1.05	3.19	1.45
	Ostrich	95	100	3.98	1.02	3.00	1.50
	Penguin	87	76	4.00	1.10	3.07	1.44
	Duck	81	100	4.31	0.84	3.00	1.45
	Pigeon	79	100	4.50	0.74	2.98	1.42
	Owl	98	97	4.37	0.92	3.34	1.51
	Chicken	45	97	4.43	0.94	3.12	1.43
Instrument	Guitar	71	100	4.52	0.77	2.45	1.11
	Banjo	95	100	4.07	1.07	2.79	1.24
	Cello	63	100	4.26	0.89	2.67	1.16
	Clarinet	47	97	3.48	1.25	2.95	1.31
	Trumpet	40	94	3.86	1.14	2.95	1.15
	Piano	55	97	4.45	0.99	3.57	1.40
	Keyboard	37	79	4.43	0.86	2.83	1.23
	Drum set	64	97	4.71	0.51	2.95	1.31
Vehicle	Bike	33	45	4.57	0.67	2.64	1.30
	Car	81	97	4.57	0.86	2.98	1.41
	tractor	38	97	3.98	1.02	3.38	1.40
	Boat	74	79	3.95	1.06	2.57	1.09
	Plane	38	94	4.10	0.97	2.90	1.24
	Bus	57	97	4.69	0.64	2.45	1.19
	Truck	50	89	4.60	0.66	2.90	1.25
	Jeep	88	97	4.64	0.69	2.95	1.41

In the Radboud faces database, there were 8 emotion label words depicting discrete emotions. The database consists of posed facial expression of various actors of differing demographics and gaze direction. For the sake of simplicity, we chose one actor (a white Caucasian male) and one gaze direction (looking directly to the participants) for the 8 emotions (see **Table 2** for more information).

Table 7

Properties of images used from the Radboud Faces Database

Image name	Name Agreement	Intensity	Valence
	%	*mean*	*mean*
Rafd090_03_Caucasian_male_angry_frontal	91	3.23	1.68
Rafd090_03_Caucasian_male_contemptuous_frontal	29	1.96	2.79
Rafd090_03_Caucasian_male_disgusted_frontal	83	3.43	2.00
Rafd090_03_Caucasian_male_fearful_frontal	83	3.91	1.91
Rafd090_03_Caucasian_male_happy_frontal	100	4.25	4.21
Rafd090_03_Caucasian_male_neutral_frontal	74	3.00	3.30
Rafd090_03_Caucasian_male_sad_frontal	87	2.96	1.78
Rafd090_03_Caucasian_male_surprised_frontal	91	3.91	2.57

Consequently, each neutral category also contained 8 exemplars to match the 8 items in the emotion label category. In total, we had 32 unique pictures.

3.3.1.3 **Design**

Participants completed a training phase in which they were trained to produce typed names for items on presentation of each image, followed by a testing phase in which they named sets of items repeatedly in a blocked-cyclic paradigm. The experiment used a within-subjects design manipulating category, relatedness and cycle. Category referred to the semantic groupings (e.g., *Emotions, Vehicles, Instruments, Animals*), relatedness referred to whether the blocks contained semantically related or unrelated items, and cycle refers to the repeated presentation of the items within each block of trials. If the members of each category interfered with one another, then naming latencies would be slower when those items appeared together in a block (related condition) compared with when they were interspersed with items from other categories (unrelated condition). Full lists of stimuli are provided in Appendix.

Pictures were presented in blocks of 16 trials. Each block contained 4 different images which were repeated 4 times (4 cycles). A related block included 4 images from the same category while unrelated blocks included 4 images from different categories. Each unrelated block consisted of one exemplar from each semantic category of interest (Emotion, Vehicles, Instruments, Birds). The cycles had a semi-random presentation of items from each category such that each exemplar from a category appeared exactly once per cycle, and at least in once each position within cycle in a block.

An example list in an unrelated block for the first two cycles was as follows: cycle 1 [ANGER, TRACTOR, CELLO, PENGUIN], cycle 2 [TRACTOR, CELLO, PENGUIN, ANGER]. Here, ANGER filled the position 1 in the first cycle, and position 4 in the second cycle. This continued until ANGER filled in position 2 and 3 in subsequent cycles. The stimuli were presented continuously per block as is typical for the blocked-cyclic paradigm (e.g., Damian & Als, 2005; Damian et al., 2001).

In related blocks, an example list was as follows: cycle 1 [ANGER, DISGUST, FEAR, HAPPINESS], cycle 2 [DISGUST, FEAR, HAPPINESS, ANGER]. Note here that ANGER maintained the position of first and fourth in the first two cycles, which was the same as in the unrelated case. This was true for all concepts (see Appendix for full lists of presentation orders in each condition). Each related block contained 4 exemplars from a single category. As we had 8 exemplars for each category in total, we created 2 related blocks for each category (see Appendix). **Figure 2** outlined the design.

3.3.1.4 **Procedure**

The participants were asked to name each picture immediately upon presentation, as per the usual picture naming task. Unlike the usual picture naming task, they were asked to type the name of the picture instead of saying it.

The participants went through two phases: a practice phase and the trial phase. In the practice phase (see **Figure 1**), they were first presented with all of the pictures used in the study with the label to be used shown below. They were asked to type the name of the picture as shown on the screen and proceeded to the next trial once they finished. After they named all 32 pictures in this way, they were required to name the same pictures again, but now without the label shown on screen. They were also given feedback on this second part of the practice phase. This was done to ensure that the participants learnt the name and were able to retrieve it correctly.

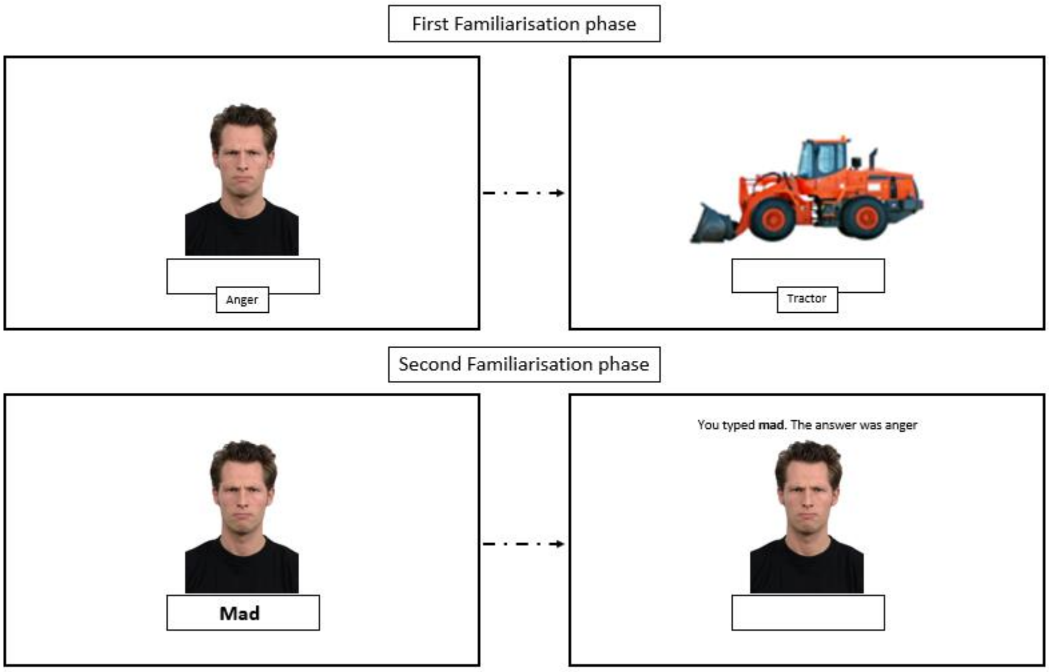

Figure 1 Familiarisation phases that each participant conducted at the beginning of the experiment. Feedback were only given in the second phase.

After the practice phase, the experimental phase began. Here, participants had to name the pictures without being shown labels or feedback. There were 16 blocks in total and each block contained 16 trials. The presentation of the blocks was randomized so each participants observed the blocks in a different random order. There were breaks after every block. The break screen stayed until participants gave response to proceed to the next block.

In each trial, they were presented with a picture at the centre of the screen and typed their answer in an empty box underneath the picture (see **Figure 2**). The picture appeared for 1600 ms and then disappeared. However, the empty box remained until they provided an answer and proceeded to the next trial. The next trial began immediately after the participant finished typing their response and pressed ENTER.

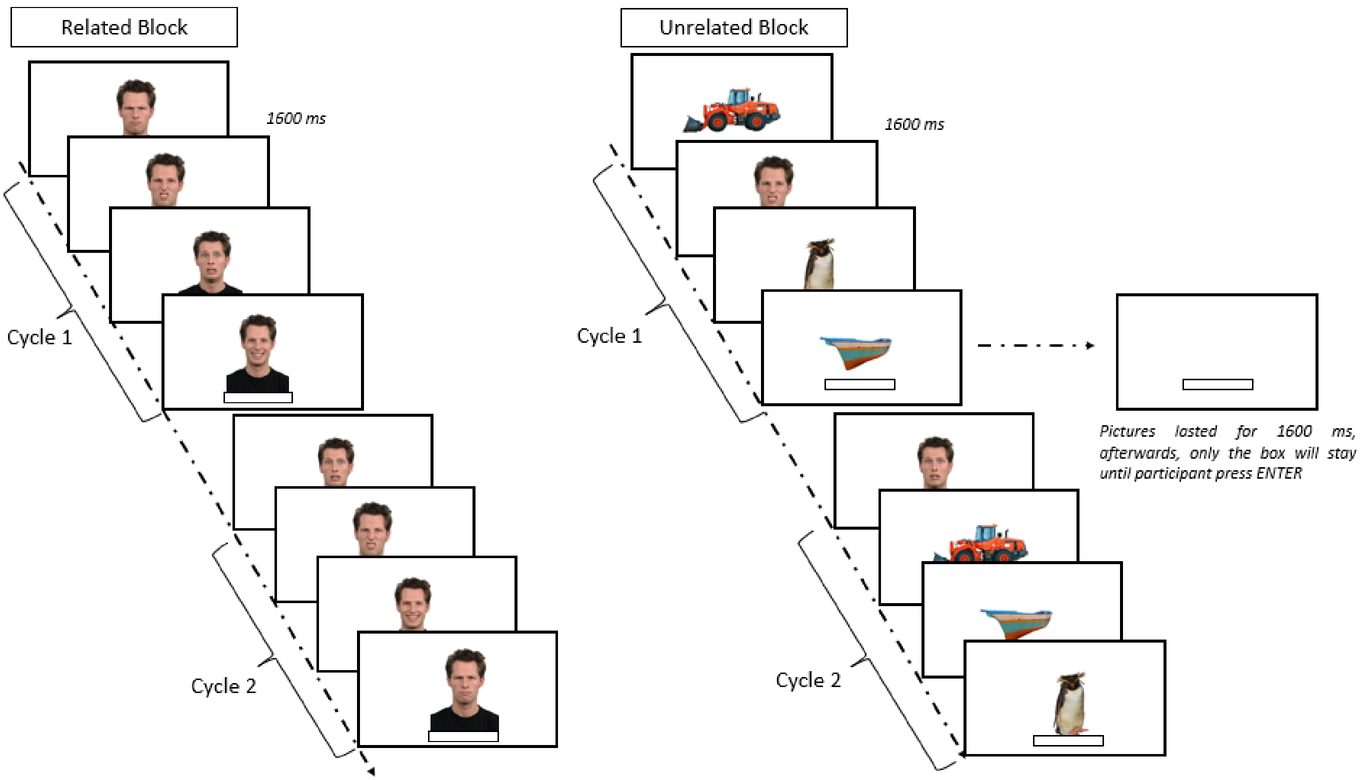

Figure 9 A representation of 2 cycles in related and unrelated blocks. In each screen, the picture was presented for 1600 ms and disappeared right after, leaving only the response box. The next trial began when the participant pressed ENTER after typing their response.

3.3.1.5 **Analysis**

All of our analysis were conducted using R-studio (version 2023.03.1+446). To determine the accuracy of the typed names, we used automated processing used by Stark et al. (2023). For this, we used Jaro distance (Jaro, 1989) to measure the degree of correctness of the typed string. A key function of Jaro distance is that it provided a heuristic metric by comparing the distance between the matching characters and the typed answer. This was under the assumption that participants' errors were genuine typo rather than randomly typed strings. We used the *stringdist*(method = "jw", p=0) in the stringdist package in R (van der Loo, 2014). We refer to Stark et al. (2023) for full description of the analysis (https://github.com/kirstenstark/stringmatch_typed_naming). Responses were considered to be correct if their Jaro distance from the target response was less than 0.4 (with 0 being similar and 1 being the least similar). For example, when naming guitar, giutar was considered correct but gittare was not.

We accepted alternative naming for some objects where there was a close synonym that was used frequently by participants. For example, we accepted *airplane* even though participants were trained to produce *plane*. The full alternative naming file could be found in the Appendix.

Results were analysed with linear mixed-effects model using the lme4 package in R (Bates et al., 2014) with the following models. We investigated the general CSI effect or *relatedness* effect for emotion pictures by comparing the reaction times between related blocks and unrelated blocks. This analysis included data for emotion pictures only. This model included fixed effects of category, relatedness and cycle and their interaction. We also conducted the same analysis for non-emotion. Additionally, we tested whether the CSI effect for emotion labels differed from that for other categories. This analysis included data from all pictures – where category was coded with two levels (emotional and non-emotional). This model included fixed effects of category, relatedness and cycle (and their interaction). While these following terms were our focus, it was still pivotal to include other aspects of the design of the experiment as a control variable. Those were *cycles* and *block order*. We were also interested in how the effect differs across cycle, so the term *cycle* was included in the interaction. *Block order* was included as a covariate to control for general changes in naming times across the experimental session.

Models included random effects of participants and items. Our analysis plans included creating a maximal model which will then be simplified following our research questions. Do note that the terms were not removed solely to achieve convergence but were guided by the research question. Reaction times that were more than 5 seconds were removed from the analysis. Additionally, reaction times were winsorised such that the upper and lower limit of the RTs were 2 standard deviations away from the mean. P-values were computed using a Wald t-distribution approximation.

3.3.2 **Results**

Participants' reaction times and accuracies are provided **Table 3**. Participants are more accurate in naming non-emotion pictures compared to emotion pictures [$t(83)=-8.104$, $p < 0.001$]. This demonstrates that naming facial expression is more difficult compared to naming objects. Participants are also highly accurate in naming the related or unrelated objects.

Table 3

Experiment 1 Summary of descriptive statistic grouped by emotions and non-emotions.

Emotionality	Relatedness	Reaction time		Accuracy	
		mean	*sd*	*mean*	*sd*
Emotion	related	1184	196	88	13
	unrelated	1041	215	89	12
Non-emotion	related	913	156	99	2
	unrelated	887	168	99	2

The reaction time (RT) were all winsorised as per our analysis procedure and referred to as RT. Mean naming latencies for related and unrelated images grouped by their categories are shown in **Figure 3**. We can see that in both categories, RTs for related blocks are faster than RTs for unrelated block.

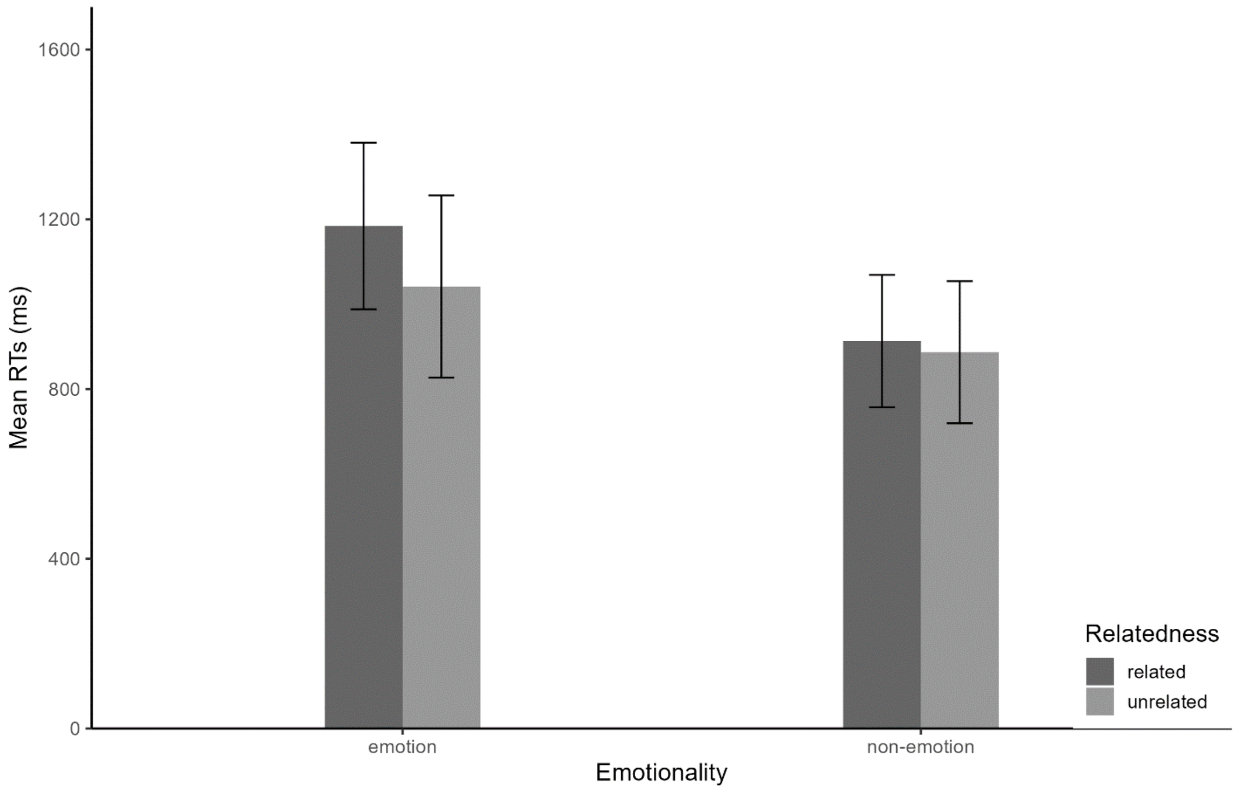

Figure 3 Bar chart of Average RT against categories by blocks. The error bar represents standard deviation.

Mean naming latencies in related and unrelated blocks broken down by cycle are shown in **Table 4**. There is an overall pattern that people were faster to name related items for the first cycle. Afterward, RT for related blocks seems to be slower in cycle 2, 3 and 4. This is the basic pattern usually seen in Blocked-cyclic paradigm which has been attributed to interference building up for each subsequent cycle (e.g., Belke, 2017).

Table 4

Experiment 1 naming latencies (milliseconds) grouped by emotions and non-emotions.

Category	Category	Cycles			
		1	2	3	4
Emotion	related	1331	1194	1190	1169
	unrelated	1420	1100	1016	1009
	difference	-88	94	174	160
Non-emotion	related	1036	930	905	904
	unrelated	1056	903	886	872
	difference	-20	27	19	32

First, we fitted a linear mixed model to predict RTs with relatedness and cycle as the predictors. We also controlled for block order by adding it as covariates. For this model, we only included emotion category to see whether there were CSI effect when naming emotion label objects (i.e., faces).

There are significant main effect of relatedness, where people were faster in naming pictures in unrelated blocks compared to related blocks [$t(8.34) = 3.461$, $p = 0.008$]. There is also a main effect of cycle in the model [$F(3)= 239.53$, $p < 0.001$] as people generally become faster as the items are repeated in each block. There is an interaction between cycle and relatedness [$F(3)= 44.82$, $p < 0.001$], as people are faster to name pictures in related block on the first cycle, but then slower to name them on subsequent cycle.

Second, we tested whether we could replicate the typical CSI effect in neutral objects. We fitted a linear mixed model to predict RT with relatedness and cycle as the predictors. There is no main effect of relatedness, indicating that overall there was no significant difference between unrelated block and related blocks for neutral objects [$t(83.88) = 1.747$, $p = 0.084$]. This is often the case when the first cycle is included in the model due to facilitation effect in the first cycle (Belke & Stielow, 2013). However, we found a significant interaction between relatedness and cycle [$F(3)= 7.07,p =0009$]. When the model was estimated omitting the first cycle, we found a main effect of relatedness [$t(65.52) = -2.539$, $p < 0.001$], replicating standard CSI effect and indicating that people were faster to name pictures in the unrelated blocks compared to related blocks in cycle 2-4. Moreover, we found a main effect of cycle, [$F(2)= 20.99,p< 0.001$] but no significant interaction between relatedness and cycle [$F(2)= 0.82,p=0.44$].

For our final analysis, we included both emotion and neutral objects in our model. We fitted a linear mixed model to predict participants' reaction time based on relatedness, category and cycle. We also controlled for the block order. The model's total explanatory power is substantial (conditional $R2 = 0.43$), and the part related to the fixed effects alone (marginal R2) is of 0.05.

The full model coefficients are shown in **Table 5**. There is a main effect of relatedness. In general, people are faster in typing the names of pictures in the unrelated than in the related block [t(75.61) = -6.70, p < .001]. This result shows that there is an overall CSI effect occurring in this data. Figure 4 shows the pattern of naming latencies grouped by emotion and non-emotion categories.

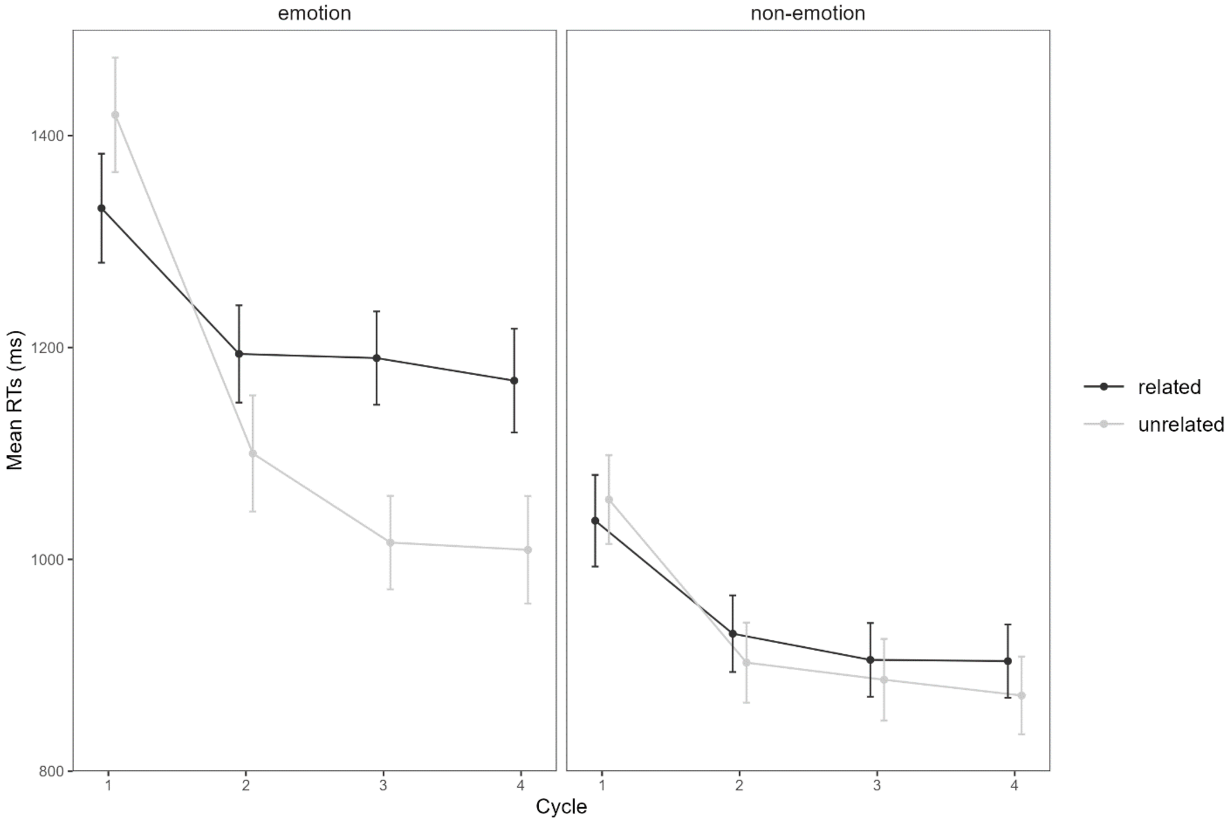

Figure 4 Mean latencies of naming objects in related and unrelated blocks broken down by cycle. The error bars represent standard error of the mean.

Table 5

Table of the estimates for the mixed models

	Reaction Time (RT)		
Predictors	Estimates	CI *[lower : upper]*	p
(Intercept)	1060.54	1012.86 : 1108.21	<0.001
Relatedness	23.97	17.16 : 30.79	<0.001
Category	117.13	86.70 : 147.55	<0.001
cycle [1]	149.96	143.06 : 156.87	<0.001
cycle [2]	-26.2	-33.09 : -19.31	<0.001
cycle [3]	-54.84	-61.70 : -47.98	<0.001
blockorder	-1.36	-2.12 : -0.60	<0.001
Relatedness * Category	16.27	10.91 : 21.64	<0.001
Relatedness * cycle [1]	-48.48	-55.39 : -41.58	<0.001
Relatedness * cycle [2]	4.23	-2.66 : 11.12	0.229
Relatedness * cycle [3]	22.55	15.69 : 29.41	<0.001
Category * cycle [1]	41.67	34.77 : 48.58	<0.001
Category * cycle [2]	-7.4	-14.29 : -0.51	0.035
Category * cycle [3]	-14.57	-21.43 : -7.71	<0.001
(Relatedness* Category) * cycle [1]	-31.66	-38.56 : -24.76	<0.001
(Relatedness * Category) * cycle [2]	-1.54	-8.43 : 5.34	0.66
(Relatedness* Category) * cycle [3]	20.15	13.29 : 27.01	<0.001
Observations	19667		
Marginal R2 / Conditional R2	0.156/0.466		

There is a main effect of emotionality – meaning that people in general named non-emotional object faster than emotional faces, [$t(35.53) = 7.55$, $p < .001$]. This result can be attributed to the difficulty of naming the emotional pictures. Indeed, we also found that people were less accurate in naming faces compared to neutral objects (see **Table 3**). Importantly, there was an interaction between the block and emotionality, meaning that the size of the CSI effect differed between the emotional and non-emotional categories. [$t(70.58) = 5.94$, $p <.001$]. As shown in **Figure 4**, larger CSI effects were found for the emotional category.

Finally, there is a main effect of cycle in the model [$F(3)= 627.70$, $p <0.001$] as people generally get faster as the items were repeated in each block. There is an interaction between cycle and relatedness [$F(3)= 67.880$, $p <0.001$], as people are faster to name related items on the first cycle, but then slower to name them on subsequent cycles.

3.3.3 **Discussion**

To summarize, we replicated the classic CSI effect, in that there was a CSI effect in our neutral categories even though we used typed rather than spoken naming. This was a novel finding as Stark et al. (2023) used continuous sequence of naming instead of a blocked-cyclic paradigm to detect CSI effect. Here, we showed that typed response can show robust CSI effects in a blocked-cyclic naming paradigm. We only found significant difference between the blocks when we excluded cycle 1. This was to be expected as cycle 1 often shows facilitation effect, in contrast with the rest of the cycles (Belke, 2017).

More importantly, our novel finding was that CSI occurs when people produce emotion labels, represented by different facial expressions. This effect was also larger than the CSI effect in the neutral categories. Having established that emotion concepts interfere with one another, we next investigate whether semantic interference occurs based on valence when one is presented with emotion-laden stimuli.

3.4 Experiment 2 – Cumulative Semantic Interference of Naming objects that are positive and negatively valenced.

In Experiment 2, we predicted that participant's naming latencies for objects would increase when we blocked images with similar emotional valence together (e.g., cemetery, shark), even though there is no direct mention of emotions. This would be analogous to the CSI effect that is present when emotion labels were retrieved directly, as seen in Experiment 1. Therefore, in Experiment 2, we investigated whether emotion-laden objects exhibit CSI effects. If they do, even without priming people to attend valence (i.e., by asking them to focus on the emotion), this indicates that people automatically process valence when accessing objects semantics (e.g., when the object's semantic representation is activated, so is its valence).

3.4.1 **Methods**

This experiment was pre-registered, and the pre-registered plan can be obtained from this link (https://osf.io/4g9zf).

3.4.1.1 **Participants**

82 participants ($Mean_{age}$ = 29.5, SD_{age} = 5.3; 46 women) participated in the study. Only 75 participants were above 80% accuracy in naming and were included in the final analysis. Participants were recruited from the online Prolific pools. All participants reported being a native English speaker, speaking English before the age of 5 and were currently living in the United Kingdom. All participants were reimbursed with money for their participation. Informed consent in accordance with the Philosophy, Psychology and Language Science Research ethics committee (PPLSREC) guidelines was obtained from each participant.

3.4.1.2 **Stimuli**

The stimuli in this experiment consisted of 4 positively valanced concepts, 4 negatively valanced concepts, and 8 emotionally neutral concepts. To represent these concepts, we selected 16 pictures in total (compared to the 32 pictures from Experiment 1) from the Open affective standardized image set database (OASIS) database (Kurdi, et al., 2017; see **Table 6** for properties of concepts in each condition). Images were selected based on valence ratings in the OASIS database. The valence groups were selected from the following the cut-off points. For positive group, we chose pictures that have a valence rating between 5 and 7. For negative pictures, we decided on s valence rating between 1 and 3. The neutral pictures were pictures with valence rating close to the midpoint of the entire database rating, which was 4.33 (See **Table 6**). Though we did not select pictures on the basis of arousal, positive and negative images tended to receive higher arousal ratings than neural images.

We also controlled for the semantic categories of the pictures. We ensured that each set of positive, negative and neutral items contained one concept from each of the following categories: aquatic animal, nature phenomenon, landscape, and mammals (see **Figure 5**).

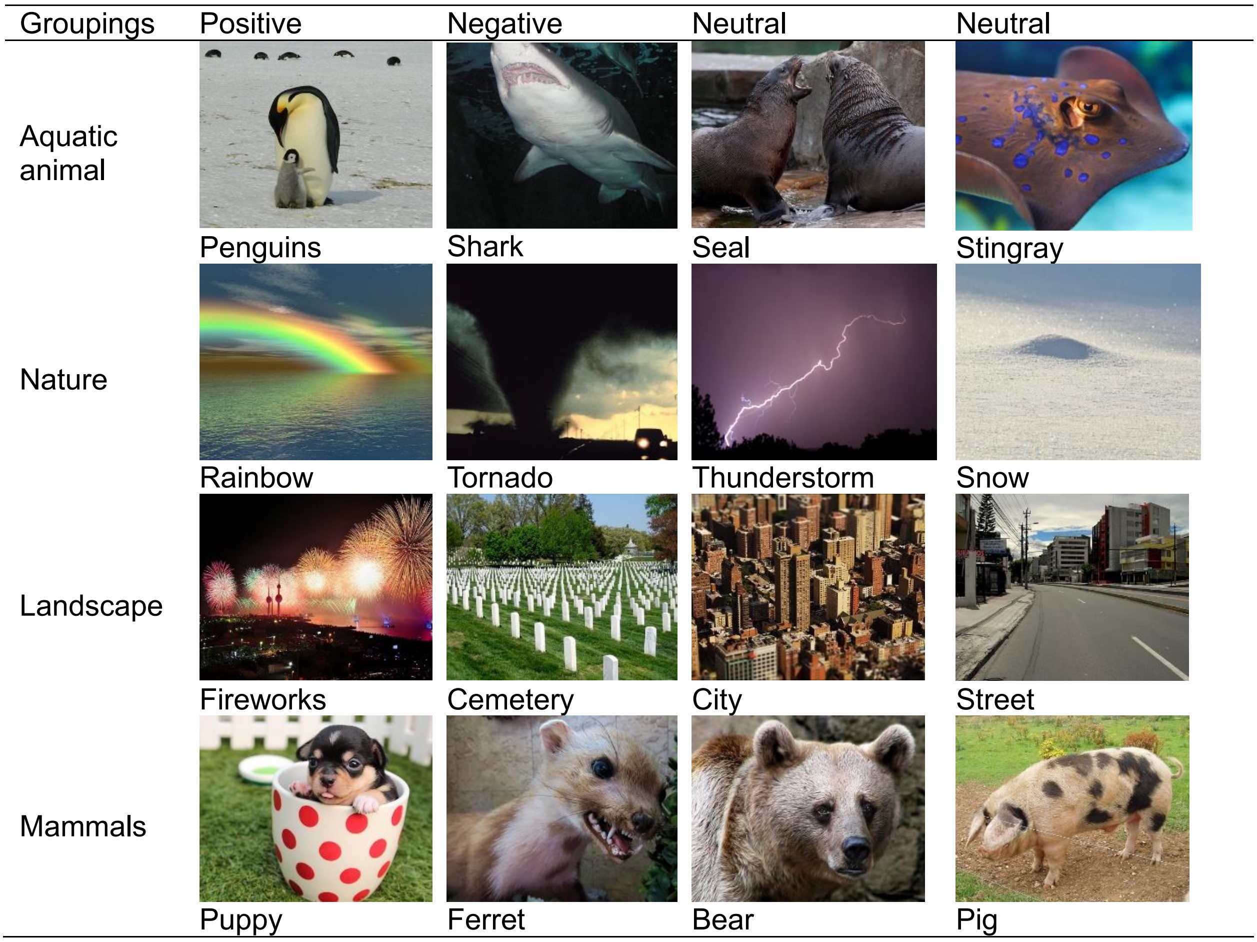

Figure 5 A figure showing all of the stimuli being used in the main experiment.

In addition, to ensure that items in a group were not semantically related and only similar in their valence, we performed a semantic relatedness analysis on each item based by their emotion groupings. Specifically, we used word2vec tool to calculate the pairwise semantic similarities for words (Mikolov et al., 2013). Briefly, word2vec tool converted words into vectors. Then, the distance between the words in the semantic space was calculated based on the dataset it was trained upon (Google News website). A cosine similarity was produced, which referred to the degree of similarity of the word pairs with 0 being the least similar and 1 being the most similar. For example, in the negative valence group, shark and cemetery had a cosine distance of 0.05, meaning that they were not similar at all. Pairwise comparison was made for each item in each valence category and an average was obtained (see **Table 6**). The low values indicate minimal semantic relationships between items in each valence category.

Table 6

Descriptive properties of valence and arousal of based on emotionality.

Valence	n	Valence	Arousal			Semantic similarity (Word2vec Cosine)	
		mean	*sd*	*mean*	*sd*	*mean*	*sd*
Positive	4	6.30	0.89	4.68	1.75	0.15	0.09
Negative	4	2.69	1.15	4.62	1.89	0.11	0.04
Neutral	8	4.44	1.09	3.38	1.56	0.09	0.09

Note: Descriptives for each item were provided in the Appendix. Values for valence and arousal were obtained from OASIS database, ranging from 1 (low valence/arousal) to 7 (high valence/arousal).

3.4.1.3 **Design**

The study was similar to Experiment 1, where naming latencies were compared between related and unrelated blocks for the same images. Specifically, it was a within subject design with 2 factors (relatedness and valence). Each factor had 2 levels (related vs unrelated blocks; positive vs negative).

Here, we were most interested in the effect of blocking between items that elicited either positive or negative emotions. Additionally, we had two neutral sets of items that acted as fillers. Importantly, each block in the experiment (related and unrelated) had one item from each of the following semantic categories: mammals, aquatic animals, nature, and landscapes. This was to control for interference caused by blocking semantic categories. This ensured that interference would not occur due to general semantic similarity, as items from the same category never appeared in blocks together. As in Experiment 1, the presentation of blocks was randomised. Each picture appeared exactly once per cycle and at each position in a cycle exactly once in each block. As in Experiment 1, position of critical items was maintained in unrelated and related blocks so their semantic interference effect could be directly compared.

In a related block, participants had to name 4 cycles of pictures that contained all the exemplars (or half the exemplars in the neutral condition) from the same valence category. Each block contained 4 cycles in each (related or unrelated) block, one item from each object category was included. For example, 2 cycles in a related block looked like: cycle 1[PENGUINS, RAINBOW, FIREWORKS, PUPPY], cycle 2[RAINBOW, FIREWORKS, PUPPY, PENGUINS]. For unrelated blocks, an example list included in the first two cycles looked like: cycle 1 [PENGUINS, TORNADO, CITY, PIG], cycle 2[TORNADO, CITY, PIG, PENGUINS]. Each unrelated block consisted of one positive valence image, one negative valence image and two neutral images. Hence, we could measure directly the interference caused when items are blocked by valence, by comparing the same items in related blocks. See **Figure 6** for a representation of the experiment.

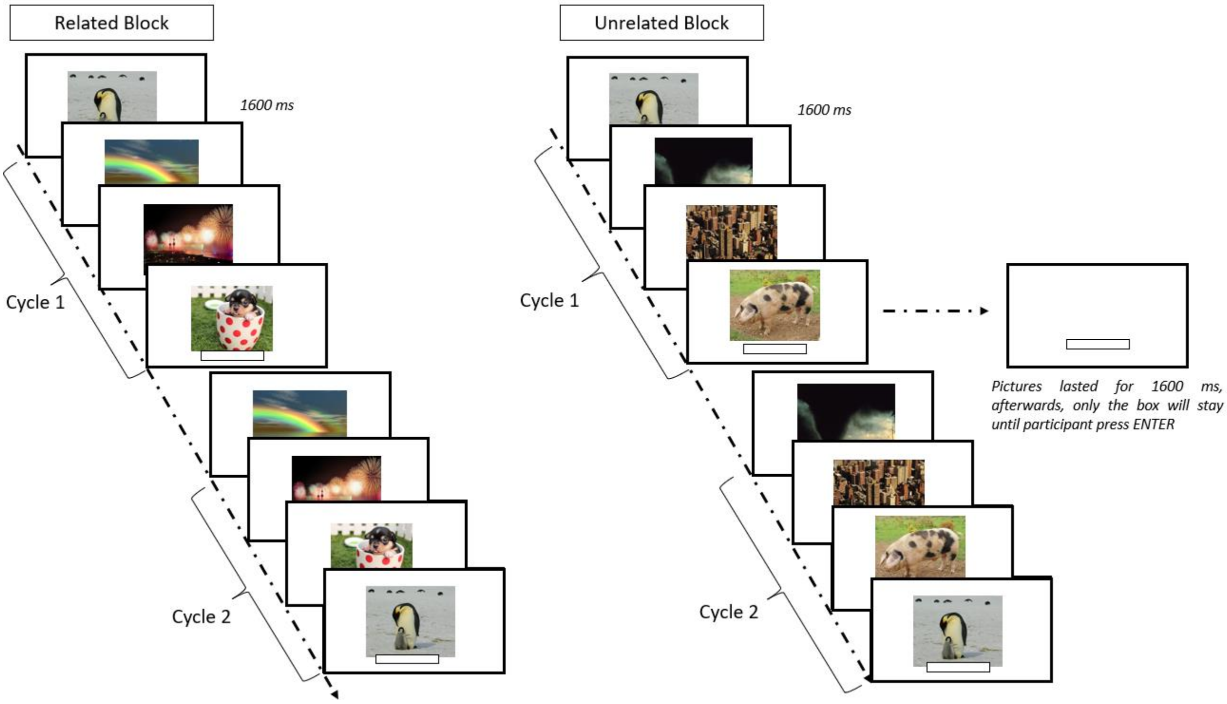

Figure 6 A representation of 2 cycles in related and unrelated blocks. In each screen, the picture stayed for 1600 ms and disappeared right after, leaving only the box. Next trial began when participant pressed ENTER.

3.4.1.4 Procedure

The procedure was the same as in Experiment 1. Participants were asked to type the name of the pictures that were presented to them, after going through the practice phase. In the practice phase, they were first presented with all pictures in turn, with the name shown below the pictures. They were asked to type the name of the picture and proceeded to the next trial once they were finished. After they named all 16 pictures, they were required to name the same pictures without the label shown on screen. They were also given feedback on this second part of the practice phase. This was done to ensure that the participants learnt the name and were not simply copying the label of the picture in the first part of the practice phase.

In the main experiment, participants completed the 4 related and 4 unrelated blocks twice each. Therefore, there were 16 blocks with 256 trials in total where each block contained 16 trials. We repeated each block twice to ensure that there was comparable number of observations to Experiment 1.

Additionally, we also included a post-naming rating phase, where participants were asked to provide valence ratings all the pictures, so we could verify whether our participants agreed with the valence rating in the OASIS database. We used the same set of instructions as were given in OASIS.

3.4.1.5 **Analysis**

We calculated the accuracy for the typed word using automated processing similar to Experiment 1. We then used linear mixed-effects model using the lme4 package in R (Bates et al., 2014). The model was similar to that used in Experiment 1, but included factors for relatedness, valence, cycle and their interactions. Furthermore, we conducted a test of difference between the participants rating of the pictures and the rating in the OASIS database.

3.4.2 **Results**

Participants' reaction times and accuracies are shown in **Table 7**. Participants are generally accurate in naming pictures in the negative and positive valence conditions. For the neutral category, they are less accurate overall. The reason for this is not clear, therefore neutral items were not included in our main analyses.

Table 7

Accuracy grouped by emotions and non-emotions.

Categories	Relatedness	Reaction time (ms)		Accuracy (%)	
		mean	*sd*	*mean*	*sd*
Negative	related	103	12	95	7
	unrelated	113	13	96	6
Positive	related	123	14	95	9
	unrelated	111	13	96	5
Neutral	related	95	11	86	3
	unrelated	113	13	86	3

Table 8 shows the average valence ratings given by participants in our study and in the OASIS. Using a T-test, we compared the mean participants' rating of negative and positive items. They differed significantly [$t(80)=30.44$, $p < 0.001$]. This means that our participants agreed closely with the valence ratings in OASIS, validating our manipulation.

Table 8

Experiment 2 Valence rating of participants and Oasis grouped by their valence.

	Participant's Valence rating		OASIS valence rating	
	mean	*sd*	*mean*	*sd*
Negative	2.40	1.36	2.69	0.04
Positive	6.21	1.04	6.30	0.09
Neutral	4.24	1.26	4.44	0.16

Mean latencies, in related and unrelated blocks are shown in **Table 9** and **Figure 7** and broken down by cycle in **Figure 8**. The differences between related and unrelated were very small, and for negative valence, the opposite pattern was observed.

Table 9

Experiment 2 naming latencies (milliseconds) grouped by Negative and positive valence. Differences between related and unrelated blocks are calculated and shown in the table.

Valence		**cycles**			
		1	2	3	4
Negative	related	910	828	816	816
	unrelated	917	839	829	822
	difference	-7	-11	-13	-6
Positive	related	886	825	810	821
	unrelated	890	813	819	813
	difference	-4	12	-8	8

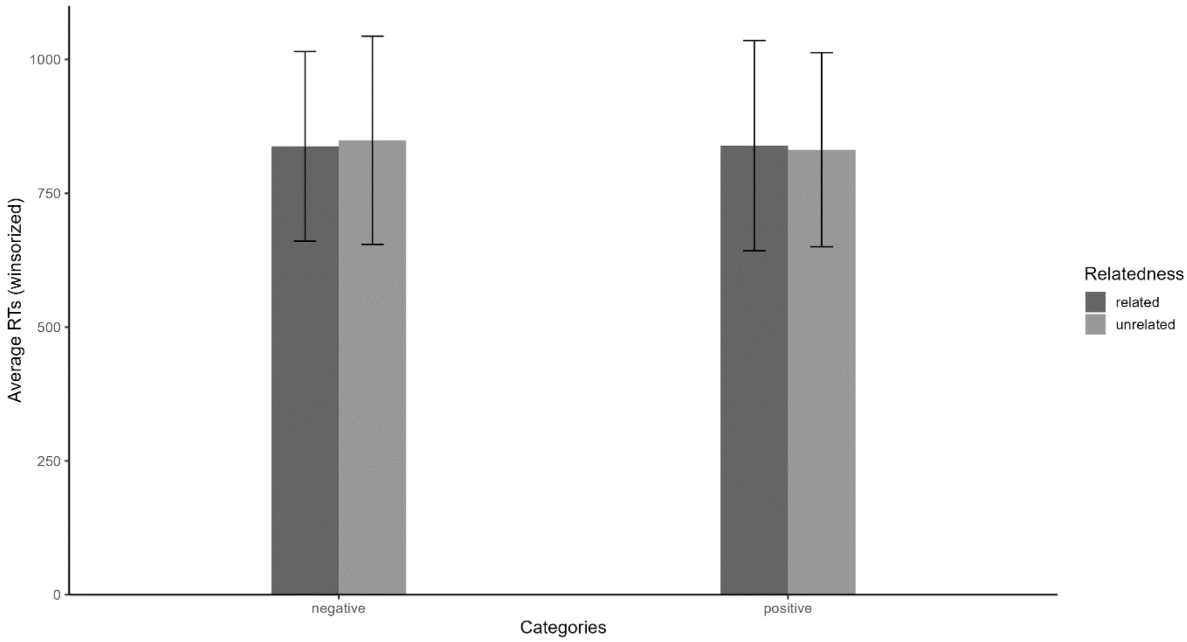

Figure 7 Bar chart of Average RT against categories by blocks. The error bar represents standard deviation.

We fitted a linear mixed model to predict reaction time from relatedness, valence and cycle. We also controlled for the block order by adding it as covariate. The model's total explanatory power is substantial (conditional R2 = 0.43), and the part related to the fixed effects alone (marginal R2) is of 0.05. **Table 10** shows the estimates for the mixed models.

There is no effect of relatedness, meaning that there are no significant differences between the naming latencies between related and unrelated blocks [t(7.09) = -0.11, p = 0.92]. This suggests that no CSI effect was observed when emotion-laden pictures were blocked by valence. There is also no main effect of valence, whereby positive pictures and negative pictures are named at similar speed in general, [t(6.17) = 0.37, p = 0.73]. This suggests that people do not find it any less difficult to name picture that represent negative valence versus pictures with positive valence.

There is a significant effect of cycle [F(3)= 192.94, p <0.001]. This suggested that people had different naming latencies in each cycle as people were slower in the first cycle compared with subsequent cycles. However, there is no significant interaction between valence and cycle [F(3) = 2.133, p =0.094]. There is also no interaction between relatedness and valence, meaning that the CSI effect do not differ between the two emotional categories [t(7.57) = -0.93, p = 0.38].

Table 10

Table of the estimates for the mixed models

	Reaction Time (RT)		
		CI	
Predictors	Estimates	*[lower : upper]*	p
(Intercept)	**870.46**	**833.23 : 907.68**	**<0.001**
Relatedness	-0.45	-8.81 : 7.92	0.917
Valence	5.21	-22.59 : 33.01	0.713
cycle [1]	**62.03**	**56.95 : 67.12**	**<0.001**
cycle [2]	**-14.14**	**-19.22 : -9.06**	**<0.001**
cycle [3]	**-24.99**	**-30.09 : -19.89**	**<0.001**
blockorder	**-3.6**	**-4.30 : -2.90**	**<0.001**
Relatedness * Valence	-4.04	-12.55 : 4.47	0.352
Relatedness * cycle [1]	-1.37	-6.46 : 3.72	0.597
Relatedness * cycle [2]	2.43	-2.65 : 7.51	0.349
Relatedness * cycle [3]	-2.47	-7.57 : 2.63	0.342
Valence * cycle [1]	5.81	0.72 : 10.90	0.025
Valence * cycle [2]	0.16	-4.92 : 5.24	0.951
Valence * cycle [3]	-1.28	-6.38 : 3.82	0.622
(Relatedness* Valence) * cycle [1]	2.4	-2.69 : 7.48	0.356
(Relatedness *Valence) * cycle [2]	-1.15	-6.23 : 3.93	0.656
(Relatedness*Valence) * cycle [3]	-1.51	-6.62 : 3.59	0.561
Observations	19667		
Marginal R2 / Conditional R2	0.045/ 0.426		

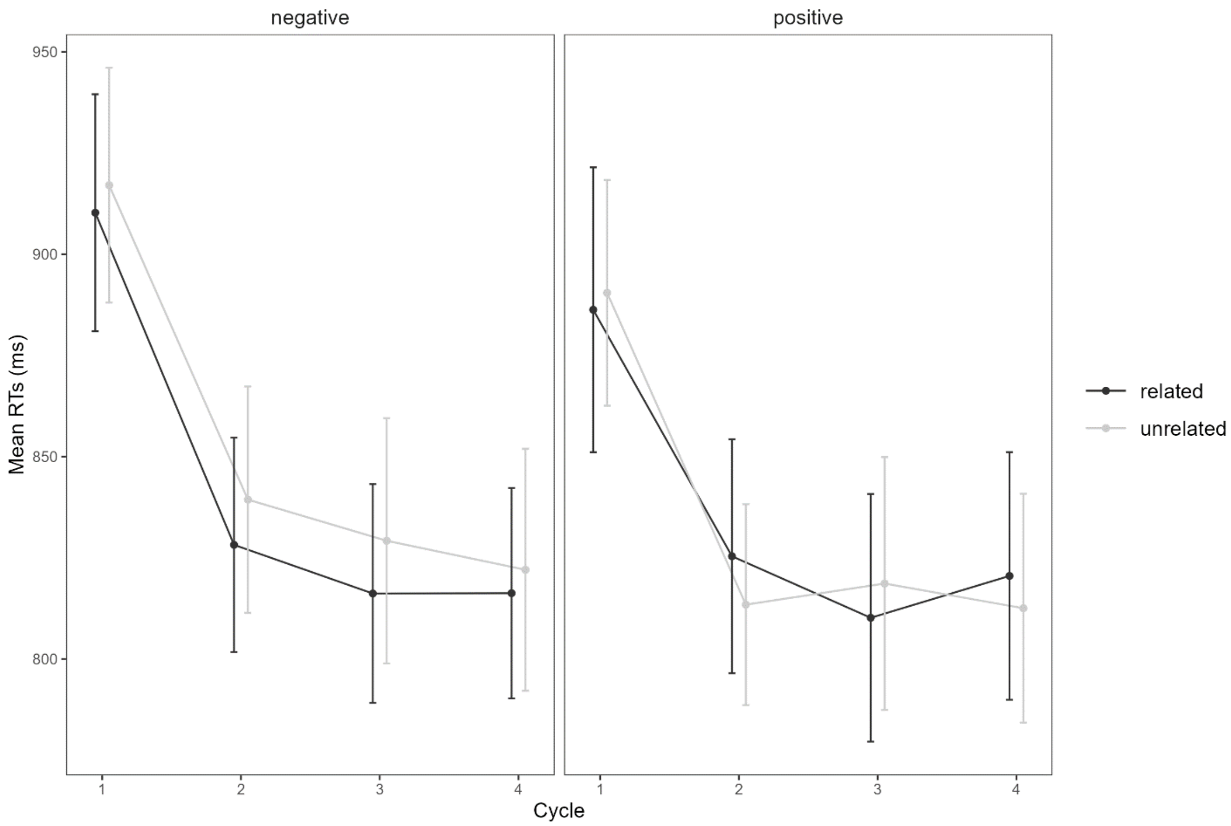

Figure 8 Mean latencies of naming objects in related and unrelated blocks broken down by cycle. The error bars represent standard error of the mean.

3.4.3 **Discussion**

Experiment 2 showed that there was no CSI effect when the items were grouped by their valence. We found that participants rated the pictures similarly to the OASIS database. This suggests that people agreed with the assigned valence of the pictures asked to judge them. However, the lack of interference suggests that either that valence information was not accessed automatically when people named the pictures, or that activated valence information was not relevant enough to the representation of the items, and so did not interfere with lexical-semantic access. For example, while a graveyard might have a sad connotation, people would not necessarily categorise a graveyard as being sad, to the extent that it interferes with processing of other items that have negative connotations. In short, we did not show that the valence dimension is an important element in the semantic representation of object concepts.

3.4.4 **General Discussion**

In this study, we used the Cumulative Semantic Interference paradigm in two experiments to investigate whether emotion-related concepts interfere with one another. In Experiment 1, we investigated whether the CSI effect could be observed when naming emotion label objects (e.g., happy, sad). In Experiment 2, we investigated whether there is a CSI effect in naming emotion-laden objects (e.g., cemetery, puppy). Additionally, we performed these experiments online and used typed responses instead of spoken responses. In Experiment 1, we found a robust CSI effect when naming emotion label objects. As far as we know, this was the first study that showed that naming facial expression, hence the emotional state, could interfere with naming consecutive emotional state when named in related and unrelated blocks. In Experiment 2, we did not find the same result when participants named emotion-laden objects. One reason could be that this might indicate that valence is not an important dimension in categorising and representing object concepts.

The findings in Experiment 1 replicated previous findings of CSI effects for object naming and extended these to the domain of emotion labels. In the first cycle, naming latencies were faster when the pictures were semantically similar (related) compared to when the group contained objects from many semantic categories (unrelated). This pattern was reversed in subsequent cycles. This pattern suggests interference built up as people repeatedly named objects from single category. In regard to neutral objects, we replicated previous findings reported elsewhere (e.g., Schnur et al., 2006; Navarete et al., 2014; Harvey & Schnur, 2016). In those studies, naming latencies in unrelated blocks were faster than related blocks. In our study, we showed the same pattern in naming facial expressions, which require access to emotion concepts. This suggests that people represent emotions as a coherent category in the semantic system, similar to how they represent that an apple belonged to a semantic group of fruits.

We also found that people were generally slower in naming the facial expression compared to the objects. People were also less accurate to name the emotional expressions compared to the neutral objects. Previous studies have found that discerning facial expressions can be difficult, especially for negative valence (Adolph & Alpers, 2010; Ekman, Sorenson & Friesen, 1969; Langner et al., 2010). However, we combated this by training participants with the labels we wanted them to use before the main experiment. This was successful: participants were well above chance in naming pictures of emotional expression and neutral objects with the correct labels. While both emotion label and neutral objects robust showed CSI effect, the differences between related and unrelated blocks in emotion label category was bigger compared to the neutral category. The high magnitude of interference observed in the emotional categories compared to the non-emotional categories was an unexpected finding. We could reason that since people already find it difficult to name the faces, the interference could be compounded by the task effect. Another possibility is that visual similarity between the images might have contributed to the effect. This could be avoided in future studies by using pictures of different actors.

Processing facial expressions was argued to activate the valence information not only reliably but also automatically. Although our study is the first to show CSI effects when naming emotional states, some other studies have shown that emotions interfere with one another in different contexts and in various automatic processing task, such as emotional Stroop task. A study by Sternberg, Wiking and Dahl (1998) asked the participants to evaluate whether a word was good or bad while the presentation of the words was superimposed on pictures of various facial expressions (e.g., happy expression for positive condition, and angry expression for negative expression). They found evaluations of positive words were facilitated while evaluations of negative words were slower when they were shown together with a picture of a happy expression compared to neutral background. Note that the participants were only required to evaluate the words instead of the pictures. The words were also grouped as positive and negative by their valence. Beall and Herbert (2008) extended this finding by also asking participants to categorise either the facial expression or the valenced words in the superimposed visual as positive or negative. They found an interference effect in the word valence judgement task compared to facial expression valence judgment task. This meant that the time to judge the valence of the words when the superimposed face was to be ignored was longer than judging the valence of the expression when the words were to be ignored. They argued that processing facial expression was more automatic compared to processing valenced words. Therefore, it was argued that merely observing facial expression was enough to automatically process valence information that it aided (or hindered) processing of emotional words. Our study has shown that emotional interference has a cumulative dimension and occurs under repeated retrieval of different emotion labels. Therefore, this further suggests that people process and categorise faces in a coherent semantic category in a picture naming task.

We also showed that typed response could demonstrate a strong CSI effect in our study. This extended Stark et al. (2023)'s study that was the first to show that typed response showed reliable CSI effect. However, they used continuous presentation of items. We showed typed responses were also sensitive to CSI effects with blocked-cyclic presentation of the stimuli. We also used similar stimuli as Harvey and Schnur (2016) in our neutral categories. We found similar pattern and magnitude when comparing the differences in our comparison between related and unrelated blocks (CSI effect). Specifically, our CSI effect is 28 ms and Harvey and Schnur (2016) is 18 ms. This was in contrast with Stark et al. (2023)'s finding that showed a higher magnitude of CSI effect between their typed response and spoken response. This could be seen in their Experiment 1 and also compared to other CSI studies (e.g., Mulatti et al., 2014).

Turning to Experiment 2, we did not find any CSI effect when we grouped object concepts by their valence. One strength of this study was that we controlled for the semantic similarity of objects in Experiment 2. This means that object concepts in each group were not semantically related to each other but was present in each of the positive, negative and neutral groups. Therefore, we could be confident in our discussion that the grouping of valence was strong in our design. Therefore, one possibility for the lack of CSI effect is that our task did not induce sufficient processing of the emotional properties of the items to cause interference.

The emotion-laden pictures might not have strongly activated any valence-related information. There was some evidence that valenced stimuli engage emotional responses implicitly and automatically. For example, in the emotional Stroop task (e.g., Ben-Haim et al., 2016), participants are required to name the colour of the ink of both emotional (e.g., death, shame) and neutral words (e.g., table, street). People took longer to name the ink of emotional words compared to neutral words. As the task was to name the ink and the word meaning were therefore irrelevant, the slower naming latencies were reasoned to reflect automatic processing of the emotional content of the words which needed to be inhibited. The emotional Stroop effect is highly reproducible and has been used in clinical studies (Williams, Mathews, MacLead, 1996).

Conversely, there is evidence that people inhibit valence processing when they focus on perceptual features. In De Houwer et al. (2001)'s third experiment, they asked participants to perform the affective Simon task using pictures. In the affective Simon task, people are asked to respond to positive or negative valenced stimuli on the basis of some non-emotional criterion (e.g., in the original AST, participants had to classify nouns as positive, and adjectives as negative; see De Houwer and Elen, 1998). People are slower when the response conflicts with the valence of the stimulus, which is taken as automatic activation of valence. De Houwer et al., (2001) asked participants presented with pictures and asked them to classify manmade objects (e.g., Chocolate) as positive and natural objects (e.g., Fire) as negative. They found the typical affective Simon effect, where people were faster to classify that chocolate as positive (as it is a positively valence object), compared to classifying chocolate as negative. However, when the images were instead classified by their perceptual features, that is positive if the image contained colour and negative if it was monochrome, the affective Simon effect was not significant. They suggested that simple perceptual processing did not elicit automatic valence processing. In our study, pre-training participants to name all of the pictures might have reduced the depth of processing during the experiment. In other words, participants may have processed the images at a shallow level that was not sufficient to activate valence information.

Additionally, we did not direct the participants to explicitly process emotional valence as they were only required to name the pictures as fast and accurately as possible. When our participants rated the pictures after finishing the main experiment, their valence rating were similar to the ones in the OASIS database. This suggested that when required, the participants were able to identify the expected valence of the pictures. However, in our study, we had no way of ascertaining whether people automatically processed the valence of the pictures during the main experiment. Previous studies using LDT showed faster reaction time when recognising positive compared to negative words (e.g., Chen et al., 2015; Scott et al., 2014), so we did not replicate fully the positivity bias effect (Waldfogel, 1948; see Walker et al., 2003 for review) or the general valence effect reported in lexical decision task (Kousta et al., 2009).

Thus, one possibility we did not observe interference in Experiment 2 might be because participants did not process the valences of the objects. An alternative possibility is that the participants did activate valence information, but this did not interfere with the process of identifying and naming the items. This would suggest that emotional associations are a less important element of the semantic representation of objects. It is also possible that a more important dimension would be arousal or even a combination of the two (or more) dimensions of emotionality. In our study, we blocked the items by their negative and positive valance. However, both of these valences shared similar arousal ratings. As noted in Sutton and Lutz (2019), arousal and other dimensions such as dominance (Russell & Mehrabian, 1977) are required to confidently categorise emotional concepts seen in facial expressions, and hence are important dimensions to be included. Future studies could investigate whether manipulating these emotional properties would induce interference effects when processing objects.

There are some studies that note the difference between the semantic and experiential properties of affective information (Robinson & Clore, 2002). This difference could be seen in how various distinction could be made in regard to processing emotions such as ‘hot’ and ‘cold’ emotions (Schaefer et al., 2003) or affective or semantic valence (Itkes & Kron, 2019). Experiment 1 could be linked to the notion of ‘hot’ emotions, whereby naming the label of the emotion activated valence information. While concepts used in our Experiment 2 could be referred to ‘cold’ emotions as we used objects that had emotional connotations.

Our results suggest some limits on the importance of valence in representing concrete words. Yao et al. (2018) asked participants to perform a lexical decision task on valence words in abstract and concrete concepts. They found that people were able to recognise emotional words defined by their valence faster compared to neutral words in both abstract and concrete words, but the emotion effect was stronger in concrete words. The authors argued that valence played a more significant role representing objects compared to abstract objects. However, our result does not lend support to the idea that valence is central to the processing of object concepts, at least not when the task requires more specific semantic processing than lexical decision.

In conclusion, we used the Cumulative semantic interference paradigm to investigate the semantic organisation of emotion labels and emotion-laden concepts. We showed for the first time that CSI occurs when emotion label concepts are blocked together. That is, a robust interference effect is observed for emotion labels, showing that these form a coherent category in semantic memory, similar to categories for concrete objects. However, no interference effect is observed for emotion-laden items of similar valence. This suggests that either emotion processing is not strongly engaged during object recognition or that valence is not central to the conceptual organisation of object concepts. In other words, this directly lend support to the ideas that affective information is not strongly activated during object concepts processing and that processing emotion label and emotion-laden words are different.

Chapter 4: I see what you feel: Using the visual world paradigm to investigate predictions based on an agent's emotional state.

4.1 **Abstract**

Many studies have highlighted the role of both linguistic and paralinguistic cues to anticipate subsequent information in language comprehension. There are also studies that have shown that people use emotional information (e.g., character's emotional state) while building situation models of emotional narratives. No studies have looked at whether people use this emotional information to predict the upcoming information. Our study addressed this question by using the visual world paradigm to investigate whether people use the emotional state of a character predictively in sentence comprehension. We asked participants to listen to sentences that described the emotional state of an agent and the cause of the emotion while tracking their eye-movements (e.g., "The boy was <u>happy</u> when the wind **blew** his favourite *kite*"). In our experiment, participants fixated more on the emotion match targets (e.g., the *kite*) compared to emotion mismatch target (e.g., the *hat*). That is, when the emotion (e.g., *happy*) was congruent with the cause of that emotion (e.g., the *kite*), participants were fixating on the target object more than when the target object was not congruent with the emotion (e.g., the *hat*) before hearing the target noun. We conclude that people use emotional information like the state of the agent automatically to predict upcoming words.

4.2 **Introduction**

Psychologists generally agree that people use some form of prediction to navigate the world around them. Specifically, in comprehending language, prediction is seen as an important cognitive computation in order to successfully communicate and facilitate rapidly unfolding social interactions (Pickering & Gambi, 2018). For example, consider the sentence “It was windy, so the boy went out to fly a kite”. Theories supporting prediction argue that people preactivate the representation of *kite* before they hear the word *kite*. In that sentence, the syntactic and semantic context restricts the selection of the final linguistic unit. Recent studies also show that people use various information in the given context (e.g., agent’s gender, prosody, facial cues) to successfully predict (e.g., Corps et al., 2022, Cao et al., 2023). But none have looked at whether emotional context, be it the emotional situation or the state of the agent itself, is used predictively. Consider the previous example with an additional context “It was windy, so the boy was happy when the wind blew his kite”, would people use the *boy’s* emotional state to predict upcoming words? This study attempts to address the gap in this literature.

Almost two decades of research has been done in regard to how people use prediction during language comprehension. A wealth of experimental evidence suggests that prediction is a mechanism that exists during language comprehension. Various behavioural studies showed that people use some form of prediction. For example, participants were found to skip words that were predictable while they were reading highly predictable content (Rayner & Well, 1996), and also fixated less on predictable versus unpredictable words (e.g., Demberg, et al., 2013; Cutter et al., 2020). In lexical decision tasks, people were also slower to respond to unpredictable words compared to predictable words (Schwanenflugel & Shoben, 1985). Additionally, various studies utilising Event related potentials (ERP) identified that sentence context reduced the ERP components associated with ease of processing (DeLong et al., 2005; Kutas & Federmeier, 2011). Specifically, the neural signal N400 was found to be reduced in a predictable sentence compared to unpredictable sentence (e.g., Maess et al., 2016). Note that while some argue that prediction is important for language comprehension (e.g., Altmann & Mirkovic, 2009; Kleinschmidt & Jaeger, 2015), others suggest that it does not happen all the time (Huettig & Mani, 2016;

Pickering & Gambi, 2018) and even impossible due to the myriad of information that people have to consider when predicting (Van Pettern & Luka, 2012 for review).

However, these studies could also be conflated with incremental processing or integration during language comprehension. Instead of showing that people anticipate words in advance, these studies can also be interpreted as showing that predictable words are easier to process and/or to integrate with the preceding context. Specifically, Pickering and Gambi (2018) outlined these following criteria to assess and hence investigate prediction in language. First, the effect needs to be shown prior to the critical word, that is, showing pre-activation that is congruent to the actual activation would constitute as evidence of prediction. Secondly, the effect should also not be attributable to bottom-up processing of word which may confound it with the explanation of integration.

Prediction in language comprehension can therefore be defined as rapid processing of linguistic and paralinguistic information before encountering the specific target that you are predicting (Pickering & Gambi, 2018). To test this, the researchers must be able to manipulate the predictability of words in a sentence context. A sentence that is predictable is regarded as a sentence that has a high cloze probability. This means that most people will continue the sentences in the same way. This rating was obtained from a procedure called a cloze procedure where in a sentence completion task, participants have to determine what is the best word to complete the sentence (Taylor, 1953). If a high proportion of people choose the same ending, the sentence is highly constraining, and the chosen ending is highly predictable. The cloze probability could also be correlated with the plausibility of the sentence (Haagoortet al., 2004; Van Berkum et al., 1999). Indeed, sentences that are predictable need to also be plausible with the provided context.

Eye tracking studies utilising the Visual World paradigm provide strong evidence that people can use prediction in language comprehension. This paradigm presents participants with spoken sentences while they were looking at a screen containing pictures while measuring their eye movements. The pictures could be presented in an array of isolated objects (Altmann & Kamide, 1999), real life scenes (Tanenhaus et al., 1995) or even a blank screen where the objects were previously located (Richardson & Spivey, 2000). For example, Altmann and Kamide (1999) presented participants with a visual scene consisting of a boy, a cake, and various other objects. The participants then heard sentences being read out such as: "*The boy will eat the cake*" or "*The boy will move the cake"*. More saccadic eye movements were given to the target word *cake* when the subsequent verb was *eat* compared to *move* before they heard the word *cake*. They proposed that since the target word *cake* was the only edible object in the visual scene, the verb *eat* restricted the participant's reference to edible object. They suggested that as the sentence unfolds, people predicted the upcoming information based on prior context, in this case, the semantic features of the target word. These contexts can also predict other linguistic information like syntax (Van Berkum et al., 2005) or form (Ito et al.,2018) or even non-linguistic information (Van Berkum et al., 2008; Corps et al., 2022, Cao et al., 2023). However, none have used visual world paradigm to look at whether people make predictions using emotional content provided in the prior context.

Why is emotional content in a text important? Many of our linguistic interactions involve discussion of social interactions or stories about how people behaved or reacted in different situations (Barrett, 2022). Understanding the emotional state of the people described could help us to anticipate upcoming events or actions and to better understand the situation involved. We likely do this by mentally simulating the agent's motivations and goals during comprehension (Zwaan, 1999) which could also include their emotional state (Gernsbacher, et al., 1992). Various studies have investigated whether people use emotional content of the text during natural reading. A series of studies used self-paced reading paradigm to investigate this question. In a seminal study, Gernsbacher et al., (1992) had participants read a passage that described an action and consequences of it (e.g., a protagonist stole money from a store and got his friend fired). Following that, participants read a target sentence that referred to emotion that was congruent (e.g., guilt) or incongruent (e.g., pride) with the previous passage. They found slower reading time when people read incongruent compared congruent sentences. They argued from their result that people were representing the emotion of the protagonist in the passage. Gygax et al, (2003) expanded on this task and compared the congruent target emotion words (e.g., guilt) with emotion words that were similar in valence but less compatible with the previous passage (e.g., sad). They found that there was no difference in reading times. They argued that while people use the emotional information of the character, they do so generally. Specifically, they posited that the representation of emotions was general (e.g., positive or negative valence) but may not instantiate specific emotions like happiness or sadness.

Recently, it has been shown that similar effects can occur with simpler narratives instead of long passages. Mumper & Gerrig, (2021) asked participants to read the sentences like "*Joe could not look his mother in the eyes when he told her he damaged her car"* that implied anger but not showing the word itself. The participants had to do a forced-choice task after reading each sentence. For example, they asked their participants to answer YES or NO if there was an emotion word in the previous sentences by showing *Guilt* on the screen. The correct answer was always NO as no explicit emotions were given in the sentences. They found that people were slower to reject emotion words that were implied in the story compared to when the passage were not implying any emotion (e.g., *Joe had to look after his mother after she damaged her eyes in a car accident).* The authors suggested that even when the emotion was not explicitly mentioned in the text, inferring emotion activated the relevant emotion representation and therefore made it difficult to say that the emotional word was not described. Importantly, this suggests that a single sentence was enough for people to construct a situation model of the event that they were trying to comprehend and that emotion in text were prevalent in the mental model that people were building. However, as argued above, their result did not show prediction. Specifically, these findings supported integration of emotion information in forming the mental model, but they did not show any evidence whether emotion information can be used predictively. Various studies have shown that people infer or represent emotional states of characters they read or hear about. But because these studies use reading time or other post-comprehension measures, they do not provide evidence that emotion information is used predictively.

Less is understood in regard to the predictive nature of emotion words. Lai and Huettig (2016) asked participants to read passages containing targets that were either predictable or not. Importantly, they also manipulated whether the target word was emotional or neutral. An example sentence that contained an emotional word in a predictable passage would be "*The book by Roald Dahl in which Charlie is the main character takes place in a factory that makes chocolate*…" where chocolate was the emotional target word compared to a neutral target word in non-predictive passage (e.g., … factory that makes *tower*). They found the similar neural signal around 200 ms (which they also identified as accessing emotion meaning) when the prediction was confirmed or when the targets were emotional. They argued that the confirmation of prediction was rewarding for the participant, leading to a similar ERP effect as reading an emotionally valanced word. However, this study does not tell us anything about whether people use emotional information to help in prediction as only the target words are emotional. Conversely, Chou, Pan & Lee (2020) also found that the enhanced P200 can be seen when the context preceding the target word was emotionally biased. Similar to Lai and Huettig's (2016) design, they also found the same effect when the target word was neutral but preceded by emotional context. Hence, they conclude that the emotional information, whether it was from the context or the emotional word itself, could facilitate processing compared to neutral words.

Ding, Wang & Yang (2020) argued that emotional verbs (e.g., *curse, encourage*) did not recruit more attentional resources compared to neutral verbs during the anticipatory stage (i.e., before 800 ms). They tested this by asking participants sentences in the format of "Neutral context + verb + noun", where the emotionality of the verb and the predictability of the nouns were manipulated. Hence, they had weakly and strongly constraining sentences that had emotional or neutral verbs. Their critical finding can be seen in the emotional verbs in highly versus weakly constraining sentences: in that, they did not find that typical effect of increased N400 due to processing unpredictable sentences. They reasoned that the resources recruited by the emotional verbs reached sufficient processing threshold to preactivate the target noun. They further suggested that emotional words were preferentially processed compared to neutral words and used during prediction as seen by the enhanced P200. Their finding supports the arousal-biased competition theory that suggest highly arousing words can facilitate processing (Lee et al., 2014).

What these studies highlighted was that emotion processing were facilitated or even preferred compared with neutral language. Additionally, the emotion terms they used were emotion-laden, meaning that they did not denote the actual emotion itself (e.g., *encourage/chocolate* instead of an emotional noun *happy*). None of these studies were interested in investigating how emotional state of the agent could contribute to comprehension predictively. As emotion label word usually describe an agent (i.e., An X is happy), it would be interesting to see whether people use the emotional words predictively.

Our current research employed a Visual world paradigm to investigate this question. We asked if knowledge of the emotional state of the agent in a sentence is used predictively during language processing. Our goal here is as follows: if people predictively use the emotional state of an agent to predict, we can argue that people use the emotional state knowledge predictively during language comprehension. As far as we know, this is the first study that used this paradigm to investigate whether people use specific emotional information predictively during sentence processing. In this study, we are investigating in the context of emotion, whether people use the emotional content of the sentence to predict upcoming words.

4.3 **Methods**

4.3.1.1 **Participants**

21 participants ($Mean_{age}$ = 23, SD_{age} =3.77, 8 males) participated in the study. Participants were recruited from a University's online advertisement website called MyCareerhub. All participants reported being a native English speaker. All participants were reimbursed with money for their participation. Informed consent in accordance with the Philosophy, Psychology Research ethics committee (PPLSREC) guidelines was obtained from each participant.

4.3.1.2 **Stimuli**

The presentation of stimuli was similar to Altmann & Kamide's (1999) design. Participants listened to sentences initially describing an agent's emotional state followed by the cause of that state, while viewing an array containing 4 objects (See **Figure 1**). The sentences contained a verb which were followed by the target object (after a few filler words). We were interested in whether people make anticipatory looks to the object most likely to have caused the emotion (i.e., the object that was congruent with the emotion of the agent). Therefore, each trial contained an array of 4 items; An emotional match object, emotional mismatch object and 2 distractors that were unrelated to the picture.

We constructed 38 pairs of sentences. Each sentence described an agent's emotional state (e.g., happy, sad) and the corresponding cause. Each pair consisted of a sentence that described a positive emotional experience of the agent or a negative experience (**Table 1**, Appendix for full list). We kept the syntax and sentence's length the same in each pair. In a pair, the target (emotion match) object for one sentence acted as the emotion mismatch object in the other.

Table 1

Example sentences for each pair of sentences. Underlined words denote emotion words, bolded words denote critical verbs, and italicized words denote target.

	Positive	Negative
Pair 1	The farmer was happy when he **found** the big *carrot*	The farmer was sad when he **found** the big *mole*
Pair 2	The faint-hearted child was happy when he **rode** the busy *carousel*	The faint-hearted child was scared when he **rode** the busy *roller coaster*
Pair 3	The fisherman was happy when he **caught** a large *fish*	The fisherman was angry when he **caught** a large *boot*

We conducted a pilot study to test the plausibility of the sentences that we constructed. This was to test how plausible each of the four images were as completions for the sentence. For example, in the event of farmer being emotional that he found something, we constructed 4 sentences (see **Table 2** for examples). Note that participants in the study only heard the emotion match sentences.

Table 2

Example sentences an event. Underlined words denote emotion words, bolded words denote critical verbs, and italicized words denote target.

Targets	Emotion	
	Positive	Negative
Emotion match	The farmer was happy when he **found** the big *carrot*	The farmer was angry when he **found** the big *mole*
Emotion mismatch	The farmer was happy when he **found** the big *mole*	The farmer was angry when he **found** the big *carrot*
Distractor	The farmer is happy when he **found** a big *hand*	The farmer was angry when he **found** the big *hand*
Distractor	The farmer was happy when he **found** the big *book*	The farmer was angry when he **found** the big *book*

We then had 41 (Mean_{age} = 19.04, SD_{age} =1.67, 30 female) participants not included in the main study rate the plausibility of the 4 sentences. Participants were instructed to rate the sentences from a scale of 1 (highly implausible) to 7 (highly plausible). Our result showed that people rated the emotion match sentence as more plausible than the distractors ($t(75) = 23.44$, $p < 0.001$). People also rated emotion congruent sentence as more plausible than emotion mismatch targets ($t(37) = 17.30$, $p < 0.001$). As expected, the distractors were not plausible endings to the sentences, but the emotional-incongruent were more plausible and emotion match were the most plausible. **Table 3** shows the mean scores of the plausibility rating.

Table 3

Mean scores (their raw scores/total unique sentences).

Targets	Mean (standard error)
Emotion match	5.69 (0.81)
Emotion mismatch	3.42 (1.03)
Distractors	2.57 (1.05)

To ensure that pictures were used equally often as the emotion match and emotion mismatch items, we performed a counterbalance by having two different lists. Each list contained half positive sentences and another half negative sentences. Each sentence described an event in two ways: describing the agent's negative or positive emotions and the matching object that caused the emotions. Thus, there were two lists in total, whereby each list either contained the positive version of the sentence or the negative version. This meant that that each list had a unique sentence that described an agent's actions and the matching causes. For example, list A had "The farmer was happy when he found a big carrot" and list B had "The farmer was sad when he found the big mole". Importantly, the type and position of the pictures were kept the same in the positive and negative versions of each sentence. Participants either saw list A or list B.

The pictures were obtained from a royalty free website from various sources. The pictures were either a realistic depiction of the object, or a cartoonish version of it. The pictures were then edited to be monochrome. To pre-test the images, we ran two picture naming studies. In the first picture naming study, 25 (Mean_{age} = 18.32, 21 female) participants not included in the main study were asked to name each candidate image with a word that best describes it in an online survey. Out of the 53 pictures that we tested, only 46 pictures showed high agreement (above 70%). We removed pictures that were named inconsistently with our target and selected new pictures that were more representative of the target word. We then asked 21 ($Mean_{age}$ = 18.86, 18 female) different participants to name the pictures. For our final set of pictures, we chose the name for each of these pictures that had the highest agreement (above 70%) to act as a target in our experiment.

The sentences were read by a text-to-speech voice obtained from natural reader website (https://www.naturalreaders.com/online/). We used an automated voice instead of recording an actual person as it made the sentence more consistent. We chose Native British English voice, called Susan, and the rate of speech was set at 140 word per minute. **Table 4** showed the mean and standard deviations of the critical words in each sentence.

Table 4

Table of mean (standard deviation) of the onsets of critical words.

Duration Descriptives	Onset (ms)		
	Emotion word	Critical verb	Target
Positive	2248 (514)	3613 (730)	4801 (864)
Negative	2171 (566)	3560 (776)	4734 (903)

4.3.1.3 **Procedure**

Participants viewed the stimuli in front of a 1024 x 768 pixel monitor. They were instructed to look at the pictures while they listened to the sentences. EyeLink 1000 Tower mount was used to record right eye movement sampled at 1000 Hz. The eye-tracker were calibrated using a nine-point grid.

Before the main experiment, the participants were familiarised with 6 trials as practice. In the main experiment, each trial began with a drift correct, followed by presentation of 4 pictures in each quadrant of the screen. The dimensions for each picture were kept constant at 300 x 300 pixels. After 1000 ms, the participants heard the sentences being played on the speaker (e.g., Corps et al., 2022). A screen with a comprehension question was shown 750 ms after the sentence finished playing. An example of a comprehension question would be “Did you hear the speaker say X?”. The participants had to either press the left button for NO or right button for YES. Half of the time, the X was the name of object that was said by the speaker, while it was a distractor in the other half. The next trial began immediately without any feedback. The participants were given the opportunity to take a break after 16 trials out of 38 trials. **Figure 1** shows the schematic of one critical trial.

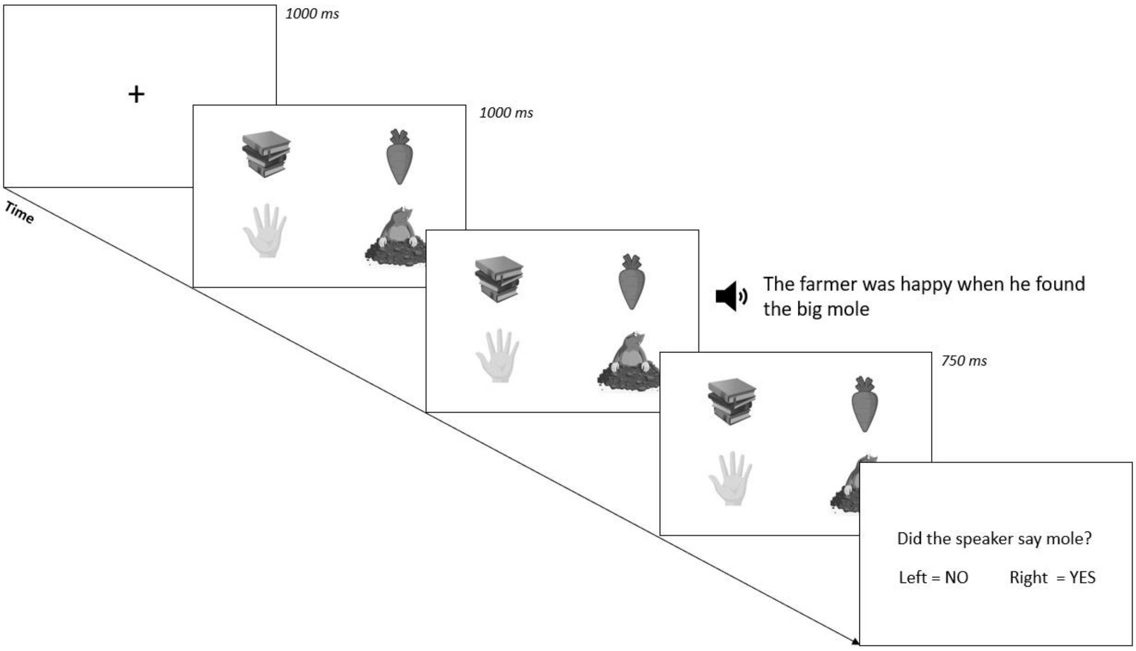

Figure 1 Schematic representation of each trial in the experiment.

4.3.1.4 **Analysis**

Our analysis was conducted using R-studio (version 2023.03.1+446). Fixations were identified by the amount of gaze that was sampled at each 50 ms time bin as per Ito et al. (2019). The fixations were coded binomially, that is, a picture was coded as 1 if it was fixated at any point within a 50 ms bin and 0 if it was not. Our research question was: Do people use emotional information predictively during sentence comprehension? We investigated this by testing whether people were more likely to look at emotion match objects compared to emotion mismatch objects.

We used a bootstrapping analysis. This analysis was used by previous studies to investigate the time point when looks to one object diverged from another (e.g., Stone et al., 2020, Corps et al., 2022). Here, we were concerned at which time point (e.g., relative to verb onset) people preferred to fixate the emotion match objects compared to emotion mismatch objects. Our prediction was as follows: If people used the emotional state of the agent to inform their predictions, we would expect fixations to be greater for emotion match objects compared to emotion mismatch objects prior to the onset of the target word. Thus, we investigated fixations in a time window around the onset of the verb.

The procedure was kept the same as previous studies that used this analysis (Corps et al., 2022). We summarise it here to give context. For each participant, the mean proportion of fixations to target and competitor items were calculated for each time bin, averaged over trials. The difference between these proportions was then submitted to one-sample t-tests to determine whether people reliably preferred the emotion congruent objects (target) over the emotion mismatch objects (competitor) at each time point. Specifically, one-sample t-tests were conducted for each time bin by comparing the relative proportion fixation for target vs. competitor to 0.5. We then sought the divergence point, i.e., the first point at which the fixations to the target and competitor diverge from each other. To do so, we looked for the first time bin by which there were a run of 10 consecutive time bins that all showed a significant difference between target and competitor. To find a statistically significant divergence point, new data sets were created following the non-parametric bootstrap of the data, by generating a new data set 2000 times by which categories such as participants, timepoint, and emotion congruency were resampled from the original dataset at each iteration. New divergence points from every iteration were obtained and the mean of these were calculated and taken as the divergence point. We obtained the confidence intervals (CIs) that showed variability around the average divergence point. This addresses the autocorrelation in the data as the data from consecutive time bins are not independent of each other.

4.4 **Results**

4.4.1 **Comprehension question accuracy**

All 21 participants were above 98% accuracy in the comprehension question.

4.4.2 **Eye tracking results**

Figure 2 shows the plot of mean fixation proportion of emotion match objects, emotion mismatch objects, and the combined distractor objects. Both distractors on each trial were equally irrelevant to the sentences, so we combined the two distractors together in our analysis. These data are time-locked to the verb onset at 0 ms. The time window in **Figure 2** was 2000 ms before and 3000 ms after the verb onset. This is a longer time window to show the general pattern of that data from the beginning of the trial to the end of it. This shows that people were more likely to fixate at the target (emotion match) when they heard it, which was expected. Importantly, however, the fixations on target preceded the onset of the target's audio presentation, beginning shortly after the verb onset. Therefore, our main analysis focuses on the period around the verb presentation.

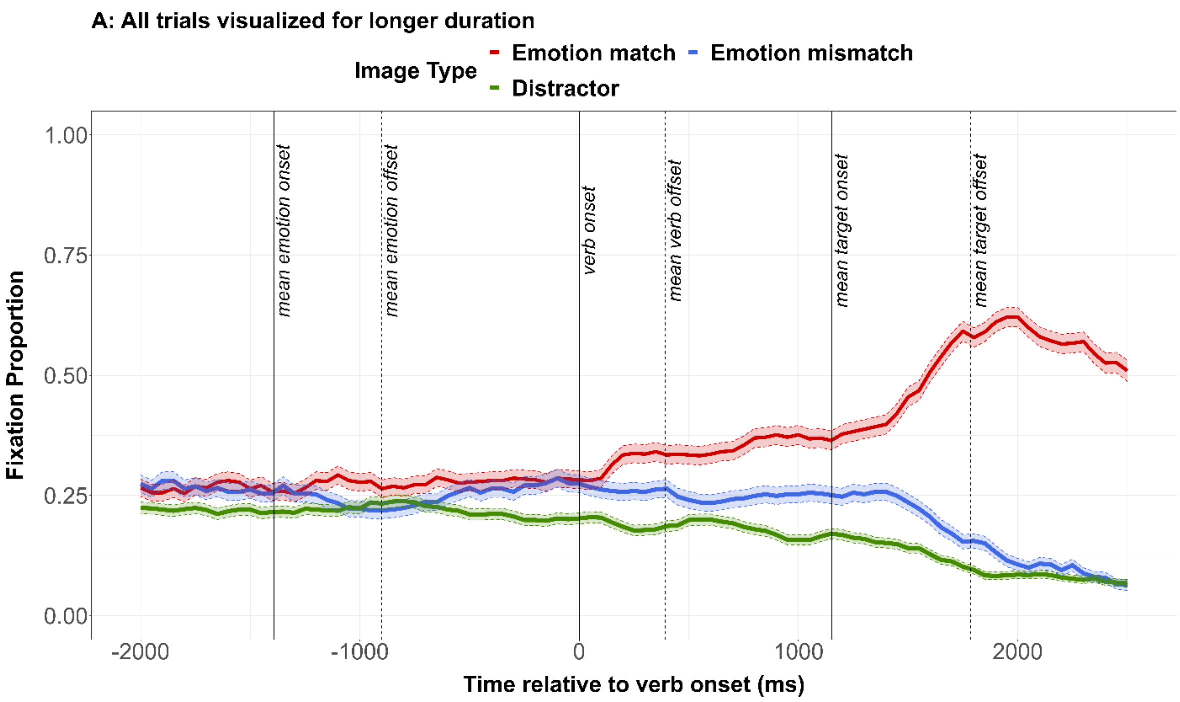

*Figure 2 Eye-tracking result for emotion match, emotion mismatch and a distractors image type timelocked at the onset of target verb. The graph shows the mean fixation proportion of emotion match trials (*The farmer was <u>happy</u> when he **found** the big *carrot), emotion incongruent (*The farmer was <u>sad</u> when he **found** the big *carrot) and distractors trial. Transparent thick lines represent standard errors.*

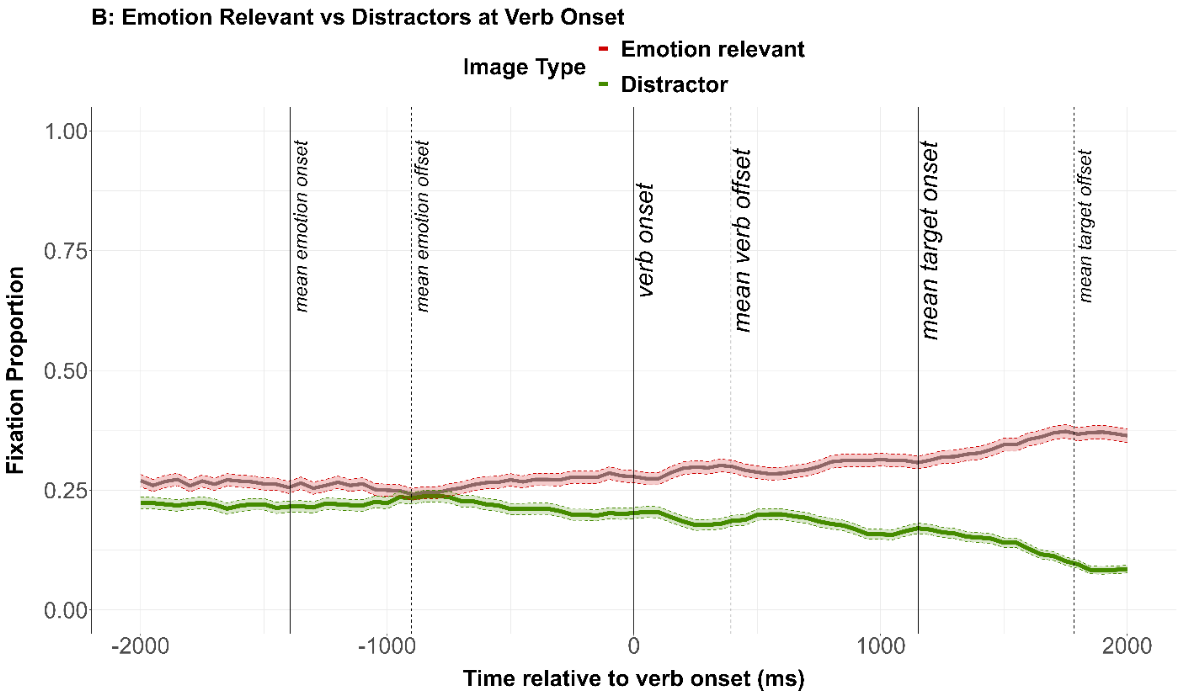

Figure 3 Eye-tracking result for all of the image type. The graph shows the mean fixation proportion of emotion relevant trials (emotion match and emotion mismatch) trial and distractors trials. Transparent thick lines represent standard error as error bars.

Figure 3 shows the mean fixation proportion at a shorter time window 2000 ms before and after the verb onset. The graph also focuses on the fixation proportion between both the emotional objects (emotion match and emotion mismatch) and the distractor objects. The bootstrapping analysis highlighted that the participants fixated more at the emotion relevant objects more than the distractor from 30 ms [CI -500 600] prior to onset of the verb. This shows that participants were more likely to look at the emotion related objects (match or mismatch) compared to distractors objects prior to hearing the verb. This is expected as both matching and mismatching objects were judged to be more plausible than distractors in the pre-test.

Figure 3 suggests that there was some divergence of fixation around the onset of emotion words. However, our bootstrapping analysis did not yield any significant divergence point, at least in 10 consecutive time bins. This suggests the likelihood of participant fixating at emotional objects was specific to the onset of the verb.

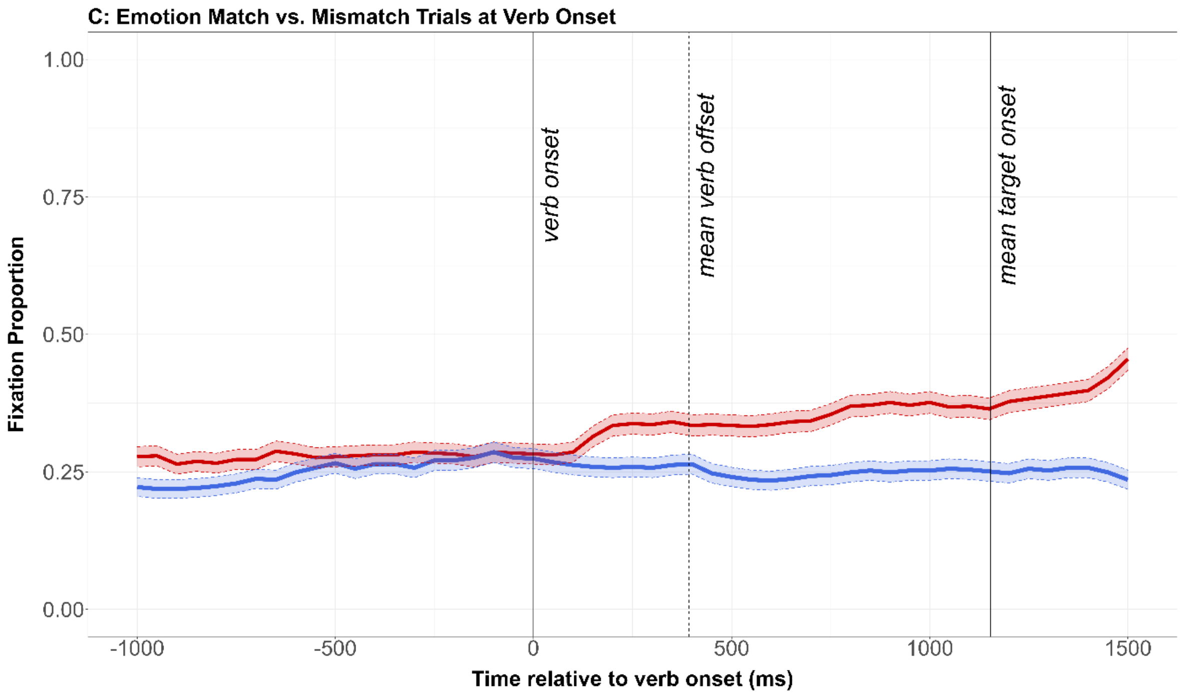

Figure 4 Eye-tracking result for emotion match versus emotion mismatch. The graph shows the mean fixation proportion of emotion match trials (RED, happy – carrot), and emotion mismatch (BLUE, sad – carrot). Transparent thick lines represent standard error.

Figure 4 shows the mean fixation proportion to emotion match vs. mismatch items, time-locked at the verb onset in the shorter time window of interest (1000 ms before and 1500 ms after the verb onset). Participants fixated on the emotion match objects more than the emotion mismatch objects after the onset of the verb. Bootstrapping analysis suggests that this divergence occurs as early as 798 ms [CI 500 1000] after the verb onset. Importantly, this indicates that participants were more likely to look at the target well before hearing the target word, indicating prediction based on the emotional state of the agent.

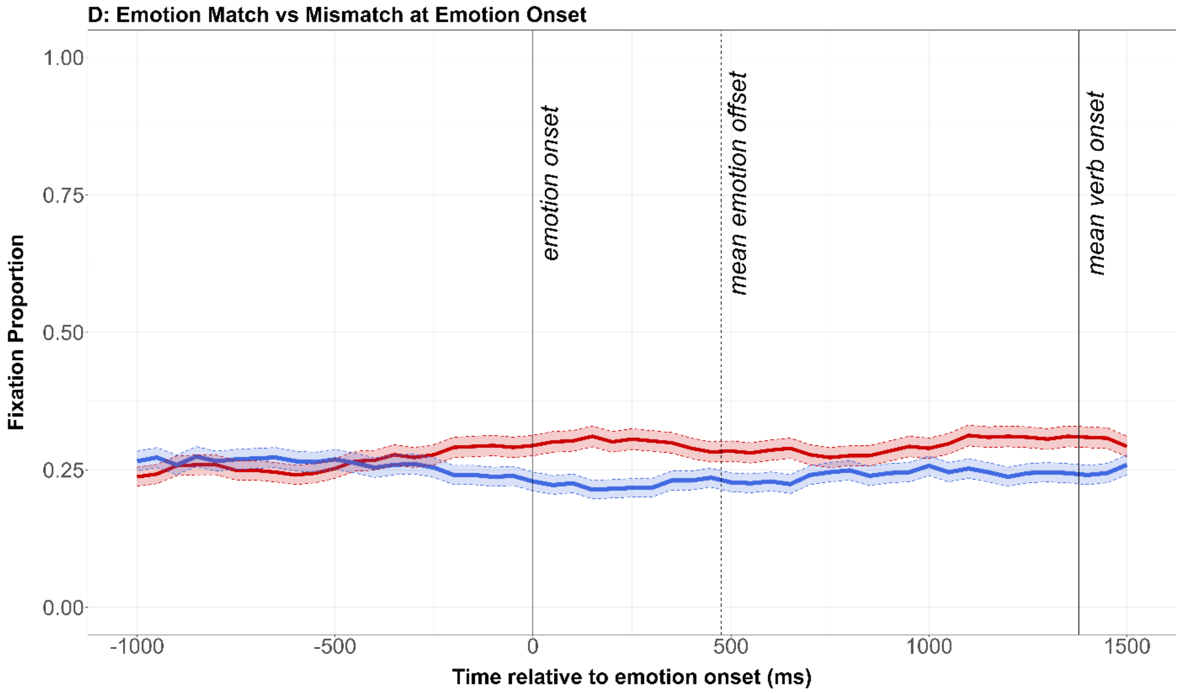

Figure 5 Eye-tracking result for emotion match versus emotion mismatch image type timelocked at the onset of emotion verb. The graph shows the mean fixation proportion of emotion match trials (happy – carrot) and emotion mismatch (sad – carrot). Transparent thick lines represent standard errors.

Finally, to investigate whether there was any divergence point around the emotion onset between emotion match and mismatch objects, we performed the bootstrapping analysis around the onset of emotion word. **Figure 5** shows the mean fixation proportion, time-locked that the start of the emotion word onset. This shows that there may have been a slight tendency for people to fixate on the emotion match items more upon hearing the emotion word. However, no significant differences were observed, indicating that reliable effects of emotion prediction only occurred after the verb onset.

4.5 **Discussion**

In this experiment, we used an eye-tracking study utilising the visual world paradigm to identify whether people use emotional information about the agent of a sentence predictively. Specifically, we asked participants to listen to sentences describing the emotional state of an agent, followed by the cause of that emotional state while measuring their eye movements. We compared the average proportion fixations between targets that provided a plausible and implausible cause for the emotion (i.e., emotion match targets and emotion mismatch targets). We predicted that the fixation proportions towards emotion match object (e.g., “carrot” in “the farmer was happy when he found the big carrot”) would be more than emotion mismatch objects (e.g., “mole” in “the farmer was happy when he found the big mole”). We investigated whether the prediction occurred if differences between the fixation proportions happened before the onset of the target nouns because they would be predicting that the utterance would mention the plausible object.

First, we replicated previous research that utilised the visual world paradigm to investigate sentence comprehension. Our experiment showed that participants rapidly fixate on objects that were semantically related to the critical verb. For example, people were more likely to fixate on ridable objects following the sentence “the faint-hearted boy was happy when he rode the busy carousel” upon hearing the word rode. This result replicated previous findings such as the hallmark study of Altmann and Kamide (1999). In that study, they highlighted the role of the verb to guide eye movement to items that were most semantically suitable to the verb. For example, more fixations were given to the verb eat compared to move in the sentence “The boy will eat/move the cake”. We showed this by comparing fixations between the emotion relevant objects and the distractors. Importantly, we found more fixations to emotional objects (which were both somewhat plausible) than distractors objects. As distractor objects were deemed to be highly implausible, the verbs were constraining the context to predict the incoming information more so than the emotion match (and emotion mismatch) objects.

More importantly, we found a novel effect of people using emotional information in a predictive way. The average fixation proportion given to emotion match objects were significantly greater compared to the looks given to emotion mismatch objects. Importantly, divergence points between the two image types occurred around 800 ms after verb onset and before the onset of the target words. As participants heard “The farmer was happy when he found the carrot”, they were more likely to look at a picture of a carrot (emotion match objects) compared to mole (emotion mismatch objects). Conversely, upon hearing “The farmer was sad when he found a big mole”, participants looked at the mole more than the carrot. This indicates that upon hearing about the farmer’s emotional state and the current situation, they inferred the most likely cause of the emotion and used this knowledge to anticipate the target. Conversely, the sentences that were describing negative emotions of the same event (e.g., The farmer was sad when he found a big mole) also had similar effect where mole was more frequently fixated than carrot. As the divergence point was observed prior to hearing the target noun, our result showed that the cause of the emotion was being predicted. As the target objects served as matching and mismatching targets equally often, we can eliminate the possibility that emotion match objects are more interesting to look at compared to their competitors. In addition, each participant only heard one version of the sentence. Therefore, participants were not primed to look at emotion match objects more so that their competitor.

The timing for our divergence point in our result is also similar to previous studies. For example, Altmann and Kamide (1999) found the divergence between predictable and unpredictable words around 610 ms. This timing of divergence was also similar to Eberhard et al., (1995) and Sedivy et al., (1999) which occurred around 550 ms to 650 ms. Recently, Corps et al., (2022) also found that the preferential of looks (i.e., divergence point) between gender match and gender mismatch to occur around 600 ms to 700 ms after the verb onset. We found that people were looking at the emotion match target more than the emotion mismatch target at 798 ms (CI [500 1000]) after the verb onset. The effect was quite rapid and could be a hallmark of prediction due to the effect occurring before the onset of the target noun (Kuperberg & Jaeger, 2016). An extension of this study could be comparing the predictability of emotional and neutral sentences to further investigate the role that emotional words play in predictive upcoming information.

As far as we know, this is the first study that showed emotional information being used predictively in sentence comprehension. Our result is compatible and extends previous inference-based studies that outlined the role of emotional state of the agent guiding comprehension of a narrative. For example, Gernsbacher et al. (1992) used self-paced reading tasks to investigate whether people inferred emotional information in a text. To do so, they asked participants to read a short text that narrated the life of a character. Importantly, the text implied specific emotions of the character (e.g., sad, bored, happy). In the critical task, the final sentence of the text was either congruent with the implied emotions or incongruent with the implied emotions. They found slower reading times in the mismatch condition compared to match condition.

This was taken as evidence that the emotional state of the character was inferred by the readers and contributed to the understanding of the text. In our study, we gave participants the emotion information directly (as opposed to implied in a text) and tested whether they inferred the cause of that emotion. Therefore, our result goes further by showing that people used emotional information about the agent in a predictive manner. In other words, our result shows people will predictably infer cause of a character's emotional state, which is likely the part of the situation model that they construct. Additionally, these inferences occur rapidly during the processing of a single sentence.

Our result also suggests that people use emotional information to guide comprehension predictively. This is also compatible with previous research. Gygax et al., (2003) posited that people were not specifically inferring the emotional state of the agent to guide their comprehension. Their study showed no difference in self-paced reading task when the match conditions (as Gernsbacher et al., 1992 design above) consisted of emotions that were synonymous or of the same valence. For example, following a text that implied negative emotion (e.g., …Joe felt something when he hit his friend when he had a long day), there was no difference between reading speed of subsequent target sentences that had similar valence (e.g., sad instead of guilty) or even unsuitable emotion word given the context (e.g., useless instead of guilty). However, they found that mismatching target sentences (e.g., sentence describing pride) were the slowest to be read which replicated Gernsbacher et al. (1992). The authors argued that instead of a character-specific emotion being used by the reader, a broad understanding of the valence of the emotion (i.e., whether it is negative or positive) was recognised and made consistent throughout the comprehension process. This means that the created situation model contained a broad description of emotion. Our design was not able to tease apart the specificity of inferring valence as our emotional conditions also broadly contained both negative and positive stimuli (e.g., happy and sad were part of the emotion match condition). This would be a question for future studies to address. Regardless, Gernsbacher et al. (1992) posited that people use general emotional state knowledge to infer and we extend this argument that people do it predictively.

Conversely, other studies pointed out that people do not take the character's perspective unless they were prompted to do so (Creer et al., 2018; O'Brien & Albrecht, 1992). In these kinds of studies, they asked the participants to read a passage indicating that a character being in a specific physical location. Then, a critical sentence mentioning another character's movement would either be consistent or inconsistent with the perspective of the character. An example passage with a consistent/inconsistent follow-up would be "Mary was standing in front of the health club" followed by "She saw the instructor come out/in the door of the club". Importantly, the authors only found disrupted reading times when the participants were instructed to read from the perspective of the characters compared to when they received no explicit instructions. Creer et al., (2018) extended this further by using a first-person perspective (e.g., 'I' instead of 'He/She') in the passages. They found disruptions in participants' reading speed in the first-person perspective even when the instructions were not explicit. They suggested that readers did not take the perspective of the character unless it was task explicit (i.e., instructions dictate perspective-taking) and text explicit (i.e., using 'I' forced reader to take the perspective). They further suggested that readers took the perspective of the protagonist, and they could only do so based on the information that they had. In our experiment, our task neither force the participants to take the characters perspective nor address the listener directly. This might imply that the underlying tasks of inferring emotion and predicting emotion can be different. It will be interesting for future studies to investigate the differences further.

In contrast, a recent study by Mumper and Gerrig, (2021) used sentence-long descriptions implying certain emotions and asked participants to identify (YES or NO) whether the previous sentences alluded to a specific emotion (e.g., guilt). They found that people were slower to reject subsequent emotional words that were implied compared to when they were not. Importantly, in their second experiment, the forced-choice task was preceded with the name of the character in the passage. They found the same result: people were slower to reject emotion words that were implied when primed with the name of a character compared to a neutral word. They suggested that this was evidence that people represent the emotional content of the character specifically when they were comprehending the sentence. One another note, Corps et al. (2022) used the visual world paradigm and found that people do take the perspective of the character during prediction in sentence comprehension. In that study, the speaker's gender and the characters that the speaker was describing were made consistent throughout sentence. Therefore, we could argue that the emotional information being used to predict was due to the emotional state of the agent rather than the general emotional content of the situation.

Note that the inference-based studies (e.g., Gernsbacher et al., 1992; Gygax et al., 2003) asked participants to infer specific emotions instead of providing participants with a clear marker of an emotion word (e.g., happy). In our study, we gave participants the name of an emotion and asked them for the cause. We could identify differences as processing emotional context (in inference-based studies) or processing emotional word (in predictive-based studies). Indeed, Chou, Pan and Lee (2020) showed that processing of emotion-laden words (e.g., positive, sweetness, losses) and context that were emotionally biased (e.g., He is busy with experiments recently, hoping to get positive result for his experiments as soon as possible) had similar neural correlates. We could take this as evidence that our result could extend these inference-based studies. Indeed, we did not design our experiment to test specific emotional inferences nor compare the result between the two. Future studies could highlight the differences between these two paradigms. Instead, we manage to show that not only can people infer emotion from a text reliably, but they could also do it predictively. Therefore, future studies could determine whether the pattern that we had here could be due to the emotional state of the agent or the implied emotional meaning of the sentence.

In our bootstrapping analysis, there was no significant difference of looks between emotion match and emotion mismatch objects at the onset of emotion word. That is to be expected as up to the onset of emotion word, there were no prior contextual cues that were given early to restrict the four objects in the array. Note that the normal procedure for our bootstrapping analysis was conducted for 10 consecutive time bins (as each time bins were 50 ms, it means that for 500 ms, the mean proportion of looks were significantly different) did not yield any significant divergent point. This is consistent with previous procedure (Corps et al., 2022). Post hoc analysis using half of the time bins (i.e., at 250 ms) showed significant divergence, but the looks converged after the offset of emotion words. This could be interpreted as: for some sentences, just the emotional state was enough to begin predicting the target, whereas for others, the additional constraints from the verb were needed for prediction to occur. This may explain the weak effect at the onset of emotion word. We entertain the possibility of the effect to be significant with larger sample size or better control of emotional valence.

In our study, we did not explicitly tell participants to focus on the perspective of the characters (e.g., farmer) nor the emotional content of the sentences. We asked people to do a simple comprehension task and they were not instructed to think specifically about the emotions or the character's perspective. We could therefore argue that our result suggests that emotion-based prediction occurs automatically. This is compatible with findings that supported the automatic activation of emotional words compared to neutral words. For example, Citron et al., (2014) asked participants to perform a lexical decision task in fMRI while viewing emotion and neutral words. Even when the task did not force any preferential processing of emotional words, they found enhanced perceptual processing of emotionally salient stimuli. This automaticity of emotional processing could also be seen in ERP studies (e.g., Su et al., 2017), in behavioural studies like the emotional Stroop task (e.g., Williams et al., 1996; Quan et al., 2020), and spatial cueing with attentional load (Okon- Singer et al., 2007). However, when the task was difficult, there would be less influence of emotion processing towards any given task (Kellermann et al., 2012). Our task was not difficult as all of our participants were correct in the comprehension task (except one with 98% accuracy). Therefore, we could conclude that people were processing the emotion information rapidly and automatically.

One strength of our study is that we did not use human speakers to narrate the sentences. Instead, our sentences were read by an online text-to-speech program which could eliminate any emotional prosody or tone that could cue people into figuring out the emotional content of the sentence until the onset of emotion word. Previous studies highlighted the role of prosody and tone in providing extra emotional content (Liebenthal et al., 2016 for review). Hence, we can ensure that the pattern in our data is due to the actual sentence content and not prosodic cues. As shown in this study, future studies could consider using text-to-speech instead of human reader to ensure consistency in various aspects of the auditory process when manipulating emotion.

Note that we chose the distractor images from a plausibility rating study as opposed to the usual indicator of predictability obtained by cloze probability task (Taylor, 1953). Specifically, sentences that contained distractor images as targets were all rated as implausible compared to sentences that contained the emotion match and mismatch images – with emotion match objects being the most plausible. However, we did not explicitly control whether both emotion relevant images were equally congruent with the verb as this was not our main interest in this study. We took the high plausibility rating of emotion match objects as an index of the sentence being predictable as both predictability and plausibility tend to be strongly correlated in sentence processing (e.g., Haagoort et al., 2004; Van Berkum et al., 1999). However, other studies have shown distinguishable temporal dynamics between predictable and plausible sentences using ERP (Quante et al., 2017). For example, Nieuwland et al., (2020) showed in a large-scale replication study that the ERP components associated with plausibility occurred later than predictability. Specifically, while both processes occurred around the N400 window (the ERP component most notably associated with lexico-semantic processing), the plausibility effect occurred at the peak of the classical N400 and went beyond as opposed to the early occurrence of predictability effect. Additionally, Huettig and Mani (2016) argued the studies that argued for prediction frequently used cloze probability procedure to inform their design. To reiterate, we used a plausibility judgment task to create our sentences. We manipulated plausibility and note that cloze probability procedure would be needed to verify whether our targets were truly predictable. However, this does not undermine our result as we wanted to test whether people predicted the most likely target, given the emotional state. Hence, plausibility seems to be a reasonable way of measuring this effect at a situation model level instead of at the lexical-specific prediction.

In sum, our study sought to investigate whether people use the emotional information of agents in a predictive way. We found evidence that people use emotional information to predict as the predictable objects were being looked at before the onset of the target compared to the competitor objects. From our data, we can conclude that people rapidly use information about emotional states to facilitate their understanding of language and predict upcoming words.

Chapter 5: General Discussion

In this thesis, I sought to investigate the link between emotion and three aspects of language processing, using three well-established psycholinguistic paradigms. I used the modality switching paradigm to investigate language comprehension, the cumulative semantic interference (CSI) for language production, and the visual world paradigm (VWP) for prediction. The results will be briefly discussed in this chapter with regard to how they relate to general theories of language and emotion.

Chapter 2 utilised the modality switching paradigm to investigate the processing differences between different classes of mental state concepts in language comprehension. I focused on emotional and non-emotional concepts. Specifically, I tested whether there were switch cost effects when participants switched between processing emotional sentences (e.g., After the scolding, she was mad) and non-emotional cognitive sentences (e.g., After the lecture, her mind was spinning). Across three experiments, I found no overall support that the emotional sentences were processed differently from cognitive sentences. Specifically, Experiment 1 does not provide evidence of a switch cost when people judge the sensibility of emotional versus cognitive sentences. This experiment focused only on sentences describing internal experiences. Experiment 2 suggests that there may be a switch cost effect in sentences that describe introspective experiences externally; however, this effect was not reproduced in Experiment 3.

In **Chapter 3**, the CSI paradigm was used to investigate whether concrete concepts were categorised by their affective properties, specifically, the valence of the object. In my two experiments, I found that there was a CSI effect when I grouped stimuli by their emotion labels (e.g., happy, sad) but not when they were grouped by their valence (e.g., puppy, graveyard). These results suggest that valence is not an important dimension that people automatically use to categorise object concepts. In Experiment 1, I found a CSI effect when people named facial expressions that depicted specific emotions. I found the typical CSI effect found in blocked-cyclic studies, where there is facilitation of reaction time in the first cycle but stayed consistent after. Importantly, blocks that contain only exemplars of a category (related block) produced longer reaction times compared to blocks intermixed with pictures from other categories. Specifically, Experiment 1 shows that emotion labels form a coherent semantic category. In Experiment 2, I found no support that valence is a key aspect of semantic processing when naming emotion-laden concepts.

In **Chapter 4**, I utilised the VWP to investigate whether people predictively use emotional information during sentence processing. Participants heard sentences describing an agent experiencing an emotional state due to a specific event (e.g., The boy was happy when the wind blew his kite) while their eye movements were recorded. Our study highlights that people predictively look at emotionally congruent objects before hearing the word denoting them. I found a deviation in looks given to the emotion-congruent object (e.g., kite) prior to hearing the word compared to objects that were incongruent (e.g., hat) with the emotion of the agent. The result indicates that people rapidly and automatically use information about someone’s emotional state to make inferences about the probable cause of that state.

5.1 **Implication and direction for future studies**

My series of experiments produced results relevant to various theories in psycholinguistics. This discussion focuses on these specific theories. That is, grounded cognition, the affective primacy hypothesis, and the situation model.

5.1.1 **Grounded Cognition**

The results in **Chapter 2** are discussed in accordance with the embodied cognition theories. The series of experiments does not provide evidence of a switch cost between emotion and cognitive sentence due to the null findings. However, I will attempt to speculate possible implication that may be relevant to the theories of embodied cognition. These results are not compatible with strong embodied theories that suggest the simulation of modality-specific regions is necessarily integral to comprehending language. Under this theory, I would expect to find a switch cost effect if sentences describing mental states require simulation in distinct affective and cognitive systems. Instead, the results are more compatible with the weak-embodied theories. Thus, there is a possibility that the semantic processes supporting these mental state events (emotional and non-emotional sentences) are processed by singular or multiple amodal systems (e.g., Mahon & Caramazza, 2008), or linguistic networks (e.g., Borghi & Binkofski, 2014; Dove, 2011), instead of relying primarily on simulations in modality-specific embodied experiential systems such as sensorimotor and interoceptive systems. Therefore, the results in **Chapter 2** suggest that there are other regions or processes that govern representations of mental states.

In **Chapter 3**, I found that blocking emotion-laden pictures (e.g., puppy) by valence did not demonstrate a CSI pattern comparable to that of blocking neutral objects by category (Experiment 2). However, there was a strong blocking effect for emotion labels elicited from faces (Experiment 1). At face value, this result shows that there is a difference between production and representation of emotion labels and emotion-laden words. Further, this finding also suggests that valence is not an important organising property for concrete concepts that directly refer to the external world. Note that this claim is limited to concepts that belong to a small subset of semantic categories, as I only investigated animals, natural, and manmade objects. Even the examples of pictures in each of these semantic categories are not extensive. However, I ensured that the items in each of these categories are not semantically related to one another, so that the groupings of these objects are only based on their valence properties. Therefore, the results clearly show that when these concepts are grouped according to their valence, no semantic interference is observed. Drawing from grounded cognition theories, my result is compatible with the general consensus that sensorimotor properties are more important contributors to the semantic representations of concrete concepts and that affective information is more salient for abstract concepts (cf. Winter, 2022). Specifically, the result in Experiment 2 shows that concepts that have strong valence properties (emotion-laden concepts) do not induce the CSI effect at all, in a naming task. Future studies could look at grouping by arousal, as it has been suggested that both valence and arousal are important dimensions to represent concepts, especially abstract concepts (Kousta et al., 2011; see Winter, 2022 for discussion on concrete concepts). Note that this paradigm frequently uses picture naming tasks, and it would be difficult to find pictures of abstract concepts.

5.1.2 **Affective primacy hypothesis**

The affective primacy hypothesis suggests that processing of emotional information (e.g., in emotional words or pictures) is automatic, such that such information is activated regardless of whether the task demands attention to the affective properties or whether the task is primed for processing emotion (Zajonc, 1980). The theory also suggests that those emotional information takes priority in processing compared to neutral information. Therefore, this theory assumes that affective information, such as valence, is automatically activated for highly affective concepts (i.e., objects with high or low ratings of valence and arousal). Evidence for this is supported by tasks such as the emotional Stroop task, lexical decision task, and affective Simon task (Citron, 2012, for review). The automaticity of emotional processing has also been observed in ERP studies (e.g., Su et al., 2017).

In Experiment 2 in **Chapter 3**, I did not find a result that supports this. The task was to name a series of pictures without alluding to any emotions or affect in the design. For example, the instructions were worded neutrally throughout, and there were no clear signs of emotional expression apart from some pictures of animals baring their teeth (which could be interpreted as angry). However, when the participants were asked to rate the valence of each picture that they saw in the experiment, the valences of the pictures agreed with the OASIS database. This suggests that participants were aware of the valence of the pictures, but only when I explicitly instructed them to rate them. In regard to affective primacy hypothesis, this result suggests that the automatic activation of affective properties might not hold for naming of concrete objects, or at least not to a sufficient degree to cause an interference effect. However, I had no way of ensuring that the participants represented the valences during the picture-naming task, and such a top-down effect can modulate the primacy of processing affective information (Chwilla, 2022; Lai et al., 2012). Future studies can further explore this topic, such as manipulating the instructions for the participants. For example, would asking participants to name the emotion they felt rather than naming the pictures build interference of valence? It is also interesting to ask whether including explicit emotional features in the presentation of the objects may also cause deliberate processing of valence and thus cause more interference. After all, Experiment 1 shows a clear CSI effect when people name the facial expression as an index emotion, which, by design, requires explicit processing of valence and arousal.

The tasks underlying these paradigms could also be an important factor to consider. In all of the experiments in this thesis, the task might not necessarily require the simulation of emotion. For example, in **Chapter 2**, the sentence plausibility judgement task might be a shallower processing task compared to the property verification task employed in past modality switching papers (Vermeulen et al., 2007). Future improvement of this study might consider using different tasks such as pleasantness judgments, to further encourage participants to process the stimuli at an affective level. Sentences denoting emotional and cognitive mental states could also be impersonal, as they refer to the mental states of generic characters (e.g., the boy, the woman). There is growing evidence that reading a first-person narrative can lead to more emotional simulations (Child et al., 2020; Wallace-Hadrill et al., 2016). It is possible that participants did not engage affectively with the sentences as they described other actors or agents. This means that the sentences may not elicit much mental simulation, as they describe the internal experiences of an anonymous third party. Since the sentences all have an introspective focus (as it describes mental state; as in Experiment 1), first-person sentences might encourage participants to engage in greater mental simulation of the experiences described. Thus, it may be more likely to observe switch costs in sentences described from a first-person perspective.

In addition, in **Chapter 3**, I made sure that the picture naming tasks was fairly neutral. In Experiment 1, when emotions were directly named using the emotion labels, the CSI was observed. In Experiment 2, the instructions were kept the same, but the categories of the pictures and the pictures themselves were changed such that they did not directly cause automatic retrieval of direct emotion concepts. Thus, my results shows that affective processing is not automatic but may depend on various factors such as task, instructions or context. This is also compatible with flexible embodiment accounts, which claim that simulations support language processing when they are needed, but not necessarily all the time (Binder & Desai, 2011; Barsalou et al., 2008)

Conversely, in **Chapter 4**, I did not explicitly tell participants to focus on the perspective of the characters (e.g., farmers) or the emotional content of the sentences. The participants performed a simple comprehension task and were not instructed to think specifically about their emotions or the character's perspective, yet clear effects of the emotional content were observed. Therefore, I argue that our results suggest that emotion-based predictions occur automatically using this paradigm. Taken together, my results seem to vary across these different psycholinguistic tasks that I employed.

5.1.3 **Situation model**

In **Chapter 4**, I found novel evidence that emotional information is used predictively by listeners during sentence comprehension. Specifically, I found that people used the emotional state of an agent to predict the ending of a sentence. They could predict the most probable cause of the emotional state of the character in a sentence, even before hearing the target word. This finding is novel and can contribute to the growing evidence that emotional information is used during sentence and narrative comprehension (Mumper & Gerring, 2021; Creer et al., 2018; see Gernsbacher et al., 1992 for the original proposal). However, many of these studies used reading time (an offline processing measure) to investigate whether participants inferred the emotion within the text, which is directly implied. My study extended this and showed that participants also use the emotional information predictively and during an online measure of processing, i.e., visual world paradigm (e.g., Altmann & Kamide, 1999)

As this is a novel finding, there are many potential directions that this finding can lead to. My experiment used simple sentences describing an internal experience of an agent (e.g., The boy is happy when the wind blew his kite). As I showed that emotion labels and emotion-laden words can have differential effects in **Chapter 3**, it is curious whether this effect can also be observed in VWP. For example, can people predict the cause of an implied emotion? Moreover, it is also interesting to test whether people could predict the congruent object when the sentences describe the external experience of the agent where the emotional state is implied (e.g., The boy smiled when the wind blew his kite).

In **Chapter 2**, I used sentences as the stimuli which may result in people constructing situation models. While **Chapter 4** provides evidence for emotional information being important in construction of situation models, there was no evidence of this in **Chapter 2**. While the sentences can be quite similar (e.g., "The boy was happy when the wind blew his kite" in **Chapter 4** vs. "He was sick with disgust" in **Chapter 2**), there are some processing differences between them. It is possible that the strong causal relationship (emotion is caused by a specific event) in sentences in **Chapter 4** encouraged people to construct a model of the event, compared to the more vague causal relationships in sentences in **Chapter 2**. This might result in people not attempting to generate models during comprehension of the sentences in **Chapter 2**. It can also be possible that the accurate eye-tracking data that VWP provides are a more sensitive measure of activation or usage of emotional information compared to switching costs, which were measured using reaction time collected online.

5.2 **Methodological considerations**

Not only did I use established psycholinguistic methods to investigate novel questions, but I also used these paradigms in an online setting, where they have rarely been used previously. Due to restrictions during the pandemic, online behavioural studies received major attention in the field during recent years, and my efforts to keep up with these trends proved to be a major challenge during the design of studies in **Chapters 2** and **3**. Regardless, utilising online data collection can be a great move forward, as the potential of accessing cohorts that are not mostly Psychology undergraduates can benefit psycholinguistic research (Garcia et al., 2022). However, there are still uncertainties in the field of online behavioural studies that future research needs to consider. For example, there is a possibility that online collection of reaction times would not be accurate enough to detect the small effect of switch costs in my modality-switching and CSI effects in my interference experiments. Previous studies using these paradigms are often conducted in the laboratory setting where all participants use the same hardware and RT recording latencies are all the same.

However, there is evidence that online data collections tools can record very accurate reaction times (Bridges et al., 2020). Fortunately, there is a growing interest in transferring production studies online, including direct comparison of spoken and typed responses using the CSI paradigm (Stark et al., 2023). Specifically, my work contributes to this effort by reproducing the effect in Stark et al. (2023) using blocked-cyclic CSI. This demonstrates the feasibility of performing this paradigm online.

I also pre-registered some of my studies using the Open Science Framework (https://osf.io/). This is an important step forward for most research in psychology, as it encourages more reproducible studies and more ethical underpinnings in designing experiments. It also aids against publication bias, as results that are otherwise not published can be easily viewed, and the pipeline for such studies can be investigated in more detail (Foster & Deaddorff, 2017). While I have only pre-registered my CSI studies, I intend to pre-register my future studies going forward.

5.3 **Conclusion**

While this thesis is ambitious, I have demonstrated the importance of using well-established psycholinguistic methods in informing and extending our understanding of the novel link between emotion and language. While still in its growing phase, we do not know much about the interaction of emotion and language, and my thesis highlights the innovative ways of using established methods to move beyond the realm of concrete (sensorimotor-based) concepts into understanding the representation basis of more abstract (emotional) concepts. To that end, innovating and improving tasks may be a fruitful endeavour to shed further light on this niche intersection in psycholinguistics. Answering the call by van Berkum (2019) in his Affective Language comprehension theory, my thesis contributes to providing more evidence linking emotion and language.

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Appendices

Chapter 1: Modality Switching Paradigm

Filler trials

Are kept the same in all experiment

the break made her giggle
the conversation made him consider his options
he regretted that he had to go
she cancelled her anguish
lazily she flipped through the fountain
passively, he participated in the seminar
he was worried about the storm
she dropped over the climb
the conversation left him confused
with sadness she told him bitter
he probed her for gossip
she climbed a steep vigour
he skipped lunch because he was not hungry
she fell down and hurt her imagination
he carefully thought out his plan
she was devastated by the strong delicacy
he talked too much whenever he was insecure
she was overcome with dangerous kittens
he took a meditation class
she kissed him at the lore
he was besotted with the girl
she thought she would go stale
he couldn't believe her regret
she considered cooking a windy meal
he directed her away from the crowd
with jealousy she hugged the cliff
she doubted whether he was in love
the drawer closed in on her
her eyes went wide with problems
the house was different than he had imagined
his motorcycle got stolen
she pitied the fallen zero
he activated the code when he came home
the smile fills her with frogs
the shame between them made her dry quickly
he had been preparing his speech for trials
they spend a lot of time in unsteadiness
his stare tingled while processing
they chopped up particles for dinner
he averted his eyes loudly
the comment hit her pale
the fearful laws ran wild
often, she walked cleanly
the story was told in a residing manner
she danced on her fists
bother was their most prized possession
the woman gave in to shows
the juice was poured in heads
to overcome her sadness, she formulated
sadness made the rocks feel sullen
the shoe missed the traces
the bridge of day made her happy
the house was painted clearly smoky
the rain made her dotted when she drove home
the meal wasn't very well yearned
she was aching all over her tears
enthusiastically, the mountain moved
she sprinkled laughter over the cake
the ants built a brick house
all her muscles were tensed because she was marginal
his bag was filled with memory
the store was faintly visible in the sky
with great effort he climbed in the door
in the morning they had instinct for breakfast
he was thinking random turns
the store wouldn't sell her balance
he shot an arrow at the tension
the whole evening was very angry
he was jealous about borders
the quality was bored
the remark responded to him with contempt
never before had the water looked this significant
the dog was sending his tail in agitation
the hero rode into art
the potatoes were enraged
the curtains were dry with fear
moral outrage washed over him

she had never protested much desire
in doubt he walked away
her expectations were lazy
he prepared his dinner in the microwave
she was not able to find a simple itch
he thought that his project would succeed
she forgot to tell her laughter
he took a handful of cookies from the plate
she plunged into the deep paper
while thinking he ate an apple
she dozed off right on target
he ran away in panic
she blinked at the seasons
he held her hand because she was afraid
she was so blended that she decided to play
the food disgusted him greatly
her monthly expression pays her house
nervously, she ate the moon
the argument did not have any consequences
she tried to appeal to his contest
the judge found him guilty
fear made her heart drive
they had a conversation about intuition
he turned around and drove back to jump
they looked like a happy couple
he couldn't shake off the codes
the castle's wall came down
everyone talked incredibly windy
she cooked a fancy dinner
swimming at the beach made her happy
they brainstormed during the whole closet
she did not believe in the power of intuition
the path was very unsure
time made a dunk
with enthusiasm he helped her out
her face betrayed that she was tired
the costs were rising above what was bolstered
generally, he did not like sports
the rain was wet with buildings
aggressively, he pushed her aside
the kindle between them is strong
his posture revealed his diary
she kicked the hut in the fight
roses tumbled over him after he washed
she cooked a pan full of concepts
he felt a sudden rise in fashion
overflowing with happiness she gave him a coral
noisily, he started to pack his guts
after a while she went to see her hence
his hands were shaking with wood
she was longing for latitude
for most of his hair he was very content
she was angered by his leaf
he smiled at her tiny
her wheel told her not to ruminate
he was stressed about the time it took to feather
sadly, she decided to go distantly
he was striped by the announcement
she drank a cup of saucy
overcome by bewilderment, he started to pause
she was thinking straight because she was entered
he hit the ball hard with his doubt
the vowel made her dizzy
he was too expressed to notice the warning
she took her legs when shovelling
he opened the present and was boxed afterwards
she dried her incentives carefully
with regret, he returned the aching book
she found out that he had bottled her
he was overcome with tables
she made dinner without using sound
because he was guilty, he spoke in carpet
absentmindedly, she stroked the cat on her spoon
out of hunger he ate eye contact
she closed the gaze
he turned away with temperature
her eyes sprinkled everywhere
intense music walked into him
she went to school and studied bluntly for a while
distracted, his eyes wandered slowly into the story
she danced for eons
following his intuition, he ran sideways
suddenly she realized that she had never been liquid
he got excited when he heard he won the concern
her toe took on a pencil position
he tried to calculate up
she poked the dog with a portal
he lurched at the blocked sea
she carefully constructed a gut feeling

he spoke about many thirsty things
remorse made her write a muscle
he is afraid because the situation laughs
she hoped she was able to sell her rumination
after a long walk, he was absolutely rated
seeing his new girlfriend made her hunch
he did not find out until trouble
when she looked up she saw center
last week he was an ashtray
the resolution considered her head
he was so busy, he didn't recognize his posture
she planted a little tide
he is in colour since she drank
she couldn't help but frown when she was expressed
the consequences of his actions were free
her face was red with sunsets
he didn't go surfing because the sea was too sick
passionately, she took part in the trunk
he had not expected to fail his knee
she sighed with theory
disgusted, he threw away both his feet
she tossed her mind in the goal
a random tentative was drawn
he looked around massively
together they took the sunset
he passed the test randomly
while rolling, the stone gestured
he had a very messy digit
her hands are drinking the tea fast
he smiled encouragingly at the street lights
she had just drawn a new beginning
he closed his fruit while being afraid
she foraged his shoulder with pity
he sympathized with the ceiling
with determination she ended the wind
his face looked lately when he dove
she drove through the guilty sands
he tried to plaster how to win
at the party she behaved very round
he didn't bare much about it
intentionally, she broke his haze
he smiled when the idea started to read
she gazed up into his hierarchy
in agony, he screamed dimly
she wanted to take the smile quickly
he could not accept the entrance
she pulled a situation in rage
his creation was criticized by cords
she tried to colour space
he biked along a stretch of mail
she did everything she could to avoid being a plum
he didn't have a very good sense of rinse
she had been grieving for a long strap
the task filled him with utensils
she really enjoyed the taste of meaning
he lay awake with moss
in reality, she did not work shiny
he regretted eating the whole game
his remark made her doubt her insect
lights spread through his arms while turning
when she was pushed, she almost lost her surprise
the bell made him stop in his frustration
her father brought her the view
he spread butter on his tea
her career was based on clouds
he held on to the maze
she had a messy look on her face
he grabbed his camera to make a blister
the moment went by completely unnoticed
she furiously broke the sentence
the train arrived at the station
she stroked the fur with memories
the road was closed because of heavy snowfall
angrily he took the wrong thought
rain washed over the city
he is sentenced with a mild boat
they played a long chess game
nothing was able to rope his sorrow
while she drove home she remembered
the moment went by in a pond
she shared her memories the whole evening
the sound was so loud it was puzzled
she failed to win the game
they waited for the storm to end in their sink
she was wondering which dress to wear
the process named the love
he saw lightning flashing in the sky
because they were very hungry, they decided to spin
he was trying to find an easy route
it linked the whole night
he went out to buy groceries
the strawberries were too hesitant to eat

his house was empty because he was moving
she came over to drink puzzlement
he walked alone for a while
above all, she just wanted to be summed
he searched in his car for the keys
she went crazy because he paired
he meditated all day long
she never felt junction like this
he was puzzled by the remark
according to the recipe, she had to add stress
while walking, the man tried to read
the expression made her afraid of honey
he recognized his old teacher
she was overflowing with behaviour
he teased her without being mean
seeing greed filled her with rent
he couldn't obscure his true intentions
the mother trembles with truth
she was starting to consolidate her make up
he took a left throb
she tripped over her patience
he was so afraid he cried flowers
she ate her manners because she was hungry
he washed the dishes with letters
she sat on the floor, falling
a rotating smile showed his delight
dizzily, she fell on the moment
quietly, he opened the label
in utter disbelief, she told him to twinkle
his insides were churning with peas
she explained the argument with great solidity
his face was cut with jealousy
she was so sad, she cried her cheeks out
he was momentarily alone with slopes
because she was tired, she went tender
while smothering he opened the sun
guilt walks down her face
the water was bending on his face
she was wrapped in self-observation
he walked towards the entrance of innovation
she hoped that the outcome was proud
he tried to think in resistance
the tree left her crude
the soles of his feet were flowering
her car drove while she was soapy
he was shamefully flooded
during the swans she left the train
he timed the moment with answers
she was mortified with peas
he couldn't stop to think about hoarse
overall, studying made her understand things coldly
he had a very lean moment
she walked on the breach
never before had he been in this rhyme
he tried to think in resistance
she took a rainy step
he ate the image
she waved at the neighbour when she hinged
he kept the lawn in bliss
she refers to tangy sceneries
fascinated, he walked towards the painting
she was drawn by burns

Practice trials

The man is watching the sunset

He was shivering when it is hot

After running, the children were tired

The dishwasher was talking loudly

The elephant was flying

The cat ran out of the room

The dog played with the stick

At night, they were happily watching the sun

Experiment 1: List of all stimuli

There were 2 groups. Group 1 saw the first prime sentences and Group 2 group saw the second prime sentences. They both saw the same target. E = emotion, C = Cognitive

Sentences	type	Group	Emotionality
He was sick with disgust	prime	1	E
He was bewildered with confusion	prime	2	C
After the scolding she was mad	target		E
He was bewildered with confusion	prime	1	C
He was sick with disgust	prime	2	E
After the lecture her mind was spinning	target		C
Confusion was felt by him after he left	prime	1	C
Guilt was felt by him after he left	prime	2	C
She was starting to cry herself to sleep	target		E
Guilt was felt by him after he left	prime	1	E
Confusion was felt by him after he left	prime	2	C
she was starting to doubt her assumptions	target		C
He was consumed by intense guilt	prime	1	E
He was consumed by intense puzzlement	prime	2	C
The happiness appeared in her mind	target		E
He was consumed by intense puzzlement	prime	1	C
He was consumed by intense guilt	prime	2	E
the image appeared in her mind	target		C
He regretted missing the opportunity	prime	1	E
He pondered the location of the key	prime	2	C
she visualized the geometrical problem	target		C
He pondered the location of the key	prime	1	C
He regretted missing the opportunity	prime	2	E
She hated the geometrical problem	target		E
He was burning with hate	prime	1	E
He was burning with concentration	prime	2	C
Her mind went completely anxious	target		E
He was burning with concentration	prime	1	C
He was burning with hate	prime	2	E
her mind went completely blank	target		C
The compliment made him proud	prime	1	E
The compliment made him complacent	prime	2	C
the revelation hit her	target		C
The compliment made him complacent	prime	1	C
The compliment made him proud	prime	2	E
The agony hit her	target		E
The funeral filled him with sorrow	prime	1	E
The lecture filled him with indifference	prime	2	C
She emptied her mind in fearfulness	target		E
The lecture filled him with indifference	prime	1	C

The funeral filled him with sorrow	prime	2	E
She emptied her mind in meditation	target		C
He loved his wife passionately	prime	1	E
He bewildered his wife immensely	prime	2	C
He retrieved the memory from his mind	target		C
He bewildered his wife immensely	prime	1	C
He loved his wife passionately	prime	2	E
He retrieved happy memories from his mind	target		E
His heart rate went up because he was angry	prime	1	E
His heart rate went down because he was meditating	prime	2	C
Wrath swirled in his head	target		E
His heart rate went down because he was meditating	prime	1	C
His heart rate went up because he was angry	prime	2	E
Doubt swirled in his head	target		C
He never felt so happy in his life	prime	1	E
He never felt so perplexed in his life	prime	2	C
A new idea formed in his mind	target		C
He never felt so perplexed in his life	prime	1	C
He never felt so happy in his life	prime	2	E
A new euphoria formed in his life	target		E
He was very disappointed after the game	prime	1	E
He was very confused after the game	prime	2	C
The answer almost infuriates her	target		E
He was very confused after the game	prime	1	C
He was very disappointed after the game	prime	2	E
The answer allowed her to ponder	target		C
He was so nervous he couldn't breathe	prime	1	E
He was so calm he breathes normally	prime	2	C
She was bewildered by what happened	target		C
He was so calm he breathes normally	prime	1	C
He was so nervous he couldn't breathe	prime	2	E
She was saddened by what happened	target		E
Being at the party filled her with happiness	prime	1	E
Being at the party filled her with awkwardness	prime	2	C
Hate swirled in his head	target		E
Being at the party filled her with awkwardness	prime	1	C
Being at the party filled her with happiness	prime	2	E
Distraction occupied her head	target		C
Her mouth went dry with fear	prime	1	E
Her mouth went dry with disbelief	prime	2	C
A renewed discipline formed from the experience	target		C
Her mouth went dry with disbelief	prime	1	C
Her mouth went dry with fear	prime	2	E
A new regret formed from the experience	target		E
Her stomach turned with nausea	prime	1	E
Her stomach turned from confusion	prime	2	C

Love made his heart race	target		E
Her stomach turned from confusion	prime	1	C
Her stomach turned with nausea	prime	2	E
Confusion made his head spin	target		C
Excitement rushed into her	prime	1	E
Insight rushed into her	prime	2	C
He was riddled with uncertainty	target		C
Insight rushed into her	prime	1	C
Excitement rushed into her	prime	2	E
He was scared of uncertainty	target		E
Embarrassment came over her	prime	1	E
Clear awareness came over her	prime	2	C
Intense anger came over him	target		E
Clear awareness came over her	prime	1	C
Embarrassment came over her	prime	2	E
Intense confusion came over him	target		C
She was overcome with feelings of despair	prime	1	E
She was overcome with attention all over her	prime	2	C
He was in doubt about his decision	target		C
She was overcome with attention all over her	prime	1	C
She was overcome with feelings of despair	prime	2	E
He was in joy about his decision	target		E
She loved her child deeply	prime	1	E
She comprehends her child immediately	prime	2	C
His heart was shattered off by rejection	target		E
She comprehends her child immediately	prime	1	C
She loved her child deeply	prime	2	E
His thoughts were thrown off by doubt	target		C
Her triumph filled her with warmth	prime	1	E
Her triumph filled her with confidence	prime	2	C
He searched his memory for the phone number	target		C
Her triumph filled her with confidence	prime	1	C
Her triumph filled her with warmth	prime	2	E
He searched his heart for hatred	target		E
Guilt overwhelmed her when she found out	prime	1	E
Doubt overwhelmed her when she found out	prime	2	C
Suddenly he knew he was sad	target		E
Doubt overwhelmed her when she found out	prime	1	C
Guilt overwhelmed her when she found out	prime	2	E
Suddenly he knew the answer	target		C
The distance between them made her sad	prime	1	E
The distance between them made her calm	prime	2	C
Doubt filled his mind all day	target		C
The distance between them made her calm	prime	1	C
The distance between them made her sad	prime	2	E
Happiness filled his mind all day	target		E
She almost choked with humiliation	prime	1	E
She almost choked with bewilderment	prime	2	C

He was anxious while learning	target		E
She almost choked with bewilderment	prime	1	C
She almost choked with humiliation	prime	2	E
his was calm while learning	target		C
She had butterflies in her stomach, when she saw him	prime	1	E
She had acted complacent, when she saw him	prime	2	C
He was confused by the statement	target		C
She had acted complacent, when she saw him	prime	1	C
She had butterflies in her stomach, when she saw him	prime	2	E
He was angered by the mockery	target		E
He has been grieving since she passed away	prime	1	E
He has been meditating since she came	prime	2	C
Looking at the food made him happy	target		E
He has been meditating since she came	prime	1	C
He has been grieving since she passed away	prime	2	E
Looking at the food made her distracted	target		C
He was hit by a pang of shame	prime	1	E
He was hit by a flash of inspiration	prime	2	C
She was thinking deeply about the subject	target		C
He was hit by a flash of inspiration	prime	1	C
He was hit by a pang of shame	prime	2	E
She was saddened deeply by the subject	target		E
His nerves were out of control	prime	1	E
his nerves reflect his calmness	prime	2	C
During yoga happiness filled her body	target		E
his nerves reflect his calmness	prime	1	C
His nerves were out of control	prime	2	E
During yoga relaxation exudes her body	target		C
Waves of embarrassment washed over him	prime	1	E
Waves of inspiration came over him	prime	2	C
She was puzzled by the sense of deja vu	target		C
Waves of inspiration came over him	prime	1	C
Waves of embarrassment washed over him	prime	2	E
She was shocked by the sense of deja vu	target		E
His guilt went to the pit of his stomach	prime	1	E
His disbelief went away quickly	prime	2	C
The phone number agitated her	target		E
His disbelief went away quickly	prime	1	C
His guilt went to the pit of his stomach	prime	2	E
The phone number came back to her in a flash	target		C
He was furious because of the argument	prime	1	E
He was confused with the argument	prime	2	C
She was indifferent after the hike	target		C
He was confused with the argument	prime	1	C
He was furious because of the argument	prime	2	E
She was happy with the hike	target		E

He was overcome by desire	prime	1	E
He was overcome with doubt	prime	2	C
Suddenly she was anxious	target		E
He was overcome with doubt	prime	1	C
He was overcome by desire	prime	2	E
Suddenly she knew where to find it	target		C
He was filled with shame because of the mistake	prime	1	E
He was filled with insight because of the mistake	prime	2	C
Her head was light with answer	target		C
He was filled with insight because of the mistake	prime	1	C
He was filled with shame because of the mistake	prime	2	E
Her head was filled with anger	target		E
Happiness energizes him	prime	1	E
Meditating energizes him	prime	2	C
She suddenly realized she was angry	target		E
Meditating energizes him	prime	1	C
Happiness energizes him	prime	2	E
She suddenly realized that she understood	target		C
He was disgusted by the comment	prime	1	E
He was unbothered with the comment	prime	2	C
She imagined being older	target		C
He was unbothered with the comment	prime	1	C
He was disgusted by the comment	prime	2	E
She was happy being older	target		E
He was ecstatic because he placed as expected	prime	1	E
He acknowledges his effort when he placed as expected	prime	2	C
She felt tense after she was reprimanded	target		E
He acknowledges his effort when he placed as expected	prime	1	C
He was ecstatic because he placed as expected	prime	2	E
She felt relaxed while she was meditating	target		C
Contempt left a bitter taste in his mouth	prime	1	E
He felt the sudden aftertaste in his mouth	prime	2	C
She thought she was going to be distracted	target		C
He felt the sudden aftertaste in his mouth	prime	1	C
Contempt left a bitter taste in his mouth	prime	2	E
She thought she was going to cry	target		E
She was terrified of what might happen	prime	1	E
She was calm on that day	prime	2	C
While dating she visualized her happy future	target		E
She was calm on that day	prime	1	C
She was terrified of what might happen	prime	2	E
While meditating she visualized the sun	target		C
She bubbled over with happiness	prime	1	E
She got over her confusion	prime	2	C

He couldn't think because he was having a headache	target		C
She got over her confusion	prime	1	C
She bubbled over with happiness	prime	2	E
He couldn't act because he was in agony	target		E
Seeing the images filled her with regret	prime	1	E
Seeing the images filled her with confidence	prime	2	C
He experiences the sudden emotion	target		E
Seeing the images filled her with confidence	prime	1	C
Seeing the images filled her with regret	prime	2	E
he experienced a sudden bolt of inspiration	target		C
She was sad because he left	prime	1	E
She was inspired because he came back	prime	2	C
He was relaxed by the end of the day	target		C
She was inspired because he came back	prime	1	C
She was sad because he left	prime	2	E
He was happy by the end of the day	target		E
Child labour made her angry	prime	1	E
Child teaching made her inspired	prime	2	C
He cheerfully experienced the moment	target		E
Child teaching made her inspired	prime	1	C
Child labour made her angry	prime	2	E
He quickly recollects the situation	target		C
In her heart, she knew she was guilty	prime	1	E
In her defence, she knew she was distracted	prime	2	C
His intuition told him not to go	target		C
In her defence, she knew she was distracted	prime	1	C
In her heart, she knew she was guilty	prime	2	E
His heart told him his true desires	target		E
She was so scared she was going crazy	prime	1	E
She was so calm during the test	prime	2	C
He was delighted with the gesture	target		E
She was so calm during the test	prime	1	C
She was so scared she was going crazy	prime	2	E
He was lost in thought	target		C
She was filled with pride after the interview	prime	1	E
She was filled with imagination after the interview	prime	2	C
Due to his calmness, he visualized the route home	target		C
She was filled with imagination after the interview	prime	1	C
She was filled with pride after the interview	prime	2	E
Due to anxiety, he lost his route home	target		E
She suffered from regret after the event	prime	1	E
She experienced the event nonchalantly	prime	2	C
Fear of heights came over him	target		E
She experienced the event nonchalantly	prime	1	C
She suffered from regret after the event	prime	2	E

Vivid imaginations came over him	target		C
Fear made her lightheaded	prime	1	E
Meditation made her clearheaded	prime	2	C
He could not think because he was distracted	target		C
Meditation made her clearheaded	prime	1	C
Fear made her lightheaded	prime	2	E
He could not think because he was ecstatic	target		E
The injustice made her enraged	prime	1	E
The system got her attention	prime	2	C
He was overcome by displeasure	target		E
The system got her attention	prime	1	C
The injustice made her enraged	prime	2	E
He was overcome by confusion	target		C
She was madly in love with him	prime	1	E
She was respecting him	prime	2	C
The remark puzzled him	target		C
She was respecting him	prime	1	C
She was madly in love with him	prime	2	E
The remark enamoured him	target		E
She was heavy with disappointment	prime	1	E
She was cognizant of the situation	prime	2	C
Her child was even more scared	target		E
She was cognizant of the situation	prime	1	C
She was heavy with disappointment	prime	2	E
Her child was even more confused	target		C
He was so prideful	prime	1	E
He was so distracted	prime	2	C
She was doubtful about where to go	target		C
He was so distracted	prime	1	C
He was so prideful	prime	2	E
She was excited about where to go	target		E
He was so embarrassed	prime	1	E
He was so experienced	prime	2	C
Her fearfulness sent her into a state of despair	target		E
He was so experienced	prime	1	C
He was so embarrassed	prime	2	E
Her dizziness sent her into a state of frenzy	target		C
The experience was a disappointment	prime	1	E
The experience was as expected	prime	2	C
She felt sense of deja vu	target		C
The experience was as expected	prime	1	C
The experience was a disappointment	prime	2	E
She felt a tinge of happiness	target		E
He was disgusted with the result	prime	1	E
He was thinking of the result	prime	2	C
She attempted to love someone	target		E
He was thinking of the result	prime	1	C
He was disgusted with the result	prime	2	E

She attempted to think of something	target		C
He is proud of his caring daughter	prime	1	E
He is thinking of his daughter	prime	2	C
She wondered why she is not understanding	target		C
He is thinking of his daughter	prime	1	C
He is proud of his caring daughter	prime	2	E
She feared she could not feel good	target		E
Contempt was felt after his action	prime	1	E
Calmness was felt after the action	prime	2	C
She managed her anger confidently	target		E
Calmness was felt after the action	prime	1	C
Contempt was felt after his action	prime	2	E
She practiced her arithmetic daily	target		C
He was ashamed and anxious	prime	1	E
He was accepting and cognizant	prime	2	C
She was dizzy as she heard the news	target		C
He was accepting and cognizant	prime	1	C
He was ashamed and anxious	prime	2	E
She was scared as she heard the news	target		E
He was distorted with grief	prime	1	E
He was bored and indifferent	prime	2	C
She was quite annoyed by the remark	target		E
He was bored and indifferent	prime	1	C
He was distorted with grief	prime	2	E
She was quite confused by the remark	target		C
He felt nervous when he was called	prime	1	E
He felt confused when he was called	prime	2	C
she was puzzled because she could not find it	target		C
He felt confused when he was called	prime	1	C
He felt nervous when he was called	prime	2	E
She was anxious because she could not find it	target		E
He was withholding his repressed anger	prime	1	E
He was withholding his answer	prime	2	C
she was happy for a bit	target		E
He was withholding his answer	prime	1	C
He was withholding his repressed anger	prime	2	E
she was confused for a bit	target		C
His integrity betrayed his guilt	prime	1	E
His integrity aligned with his thoughts	prime	2	C
She had a revelation	target		C
His integrity aligned with his thoughts	prime	1	C
His integrity betrayed his guilt	prime	2	E
She had a joyful time	target		E
Out of guilt he returns the wallet	prime	1	E
Out of whim he returned the wallet	prime	2	C
She was very mad	target		E
Out of whim he returned the wallet	prime	1	C
Out of guilt he returns the wallet	prime	2	E

She was very surprised	target		C
He succumbed to his disgust	prime	1	E
He fell for the magician's tricks	prime	2	C
He is thinking about his latest hobby	target		C
He fell for the magician's tricks	prime	1	C
He succumbed to his disgust	prime	2	E
He is enjoying his latest hobby	target		E
He felt a rush of happiness	prime	1	E
He felt the calmness of the situation	prime	2	C
He was so scared of the task	target		E
He felt the calmness of the situation	prime	1	C
He felt a rush of happiness	prime	2	E
He was so focused on the task	target		C
She was red with embarrassment	prime	1	E
She was distracted with the situation	prime	2	C
Puzzled, he stopped in his tracks	target		C
She was distracted with the situation	prime	1	C
She was red with embarrassment	prime	2	E
Scared, he stopped in his tracks	target		E
She was full of excitement	prime	1	E
She was full of thoughts	prime	2	C
He was indeed agonizing on his studies	target		E
She was full of thoughts	prime	1	C
She was full of excitement	prime	2	E
He was indeed concentrating in his studies	target		C
She felt lonely	prime	1	E
She felt confused	prime	2	C
He was focused on the match	target		C
She felt confused	prime	1	C
She felt lonely	prime	2	E
He was entertained during the match	target		E
Her fear got the best of her	prime	1	E
Her confusion got the best of her	prime	2	C
The girl was happy by the random act	target		E
Her confusion got the best of her	prime	1	C
Her fear got the best of her	prime	2	E
The girl was puzzled by the random act	target		C
She lit up with happiness	prime	1	E
She lit up with confidence	prime	2	C
She visualized her path to success	target		C
She lit up with confidence	prime	1	C
She lit up with happiness	prime	2	E
She agonized her path to success	target		E
She felt deep regret	prime	1	E
She felt deep insight	prime	2	C
He regretted his own question	target		E
She felt deep insight	prime	1	C
She felt deep regret	prime	2	E

He answered his own question	target		C
Her heart was filled with rage	prime	1	C
Her heart was filled with calmness	prime	2	C
Drawing the route helped him visualize	target		C
Her heart was filled with calmness	prime	1	C
Her heart was filled with rage	prime	2	E
Drawing the route lessen his anxiety	target		E
She shifted her anger at the injustice	prime	1	C
She shifted her focus at the target	prime	2	C
During examination, he was anxious	target		E
She shifted her focus at the target	prime	1	C
She shifted her anger at the injustice	prime	2	E
During meditation, he was calm	target		C
The fleeting moment saddened her	prime	1	C
The current time confused her	prime	2	C
He was confused when his expectation fell apart	target		C
The current time confused her	prime	1	C
The fleeting moment saddened her	prime	2	E
He was scared when his expectation fell apart	target		E

Experiment 2: List of all stimuli

There were 4 groups. Each person in a group saw prime sentences corresponding to their Group number (E.g., Group 1 saw sentences labelled 1 only and the targets). They all saw the same target. Emotionality; E = emotion, C = Cognitive. Focus; I = Internal, E = External

Sentences	Group	Sentence type	Focus	Emotionality
Looking at the food made her hungry	1	prime	I	N
He was sick with disgust	2	prime	I	E
Her face was pale with exhaustion	3	prime	E	N
He waved his arms ecstatically	4	prime	E	E
His chest swelled with pride		TARGET	E	E
His hands were shaking because he was terrified	1	prime	E	E
she was thinking deeply about the subject	2	prime	I	N
Guilt washed over him after he left	3	prime	I	E
She stopped, doubtful about where to go	4	prime	E	N
His voice trembled with embarrassment		TARGET	E	E
She licked her lips because she was hungry	1	prime	E	N
Happily, he grinned from ear to ear	2	prime	E	E
During yoga tension left her body	3	prime	I	N
He was consumed by guilt	4	prime	I	E
His body slumped with disappointment		TARGET	E	E
He regretted missing the opportunity	1	prime	I	E
She gasped at the sense of deja vu	2	prime	E	N
He stared at the girl with desire	3	prime	E	E

She was puzzled by the sense of deja vu	4	prime	I	N
His nose wrinkled with disgust		TARGET	E	E
The phone number came back to her in a flash	1	prime	I	N
He was burning with hate	2	prime	I	E
She stared blankly into space	3	prime	E	N
He looked around nervously	4	prime	E	E
He embraced his wife lovingly		TARGET	E	E
She was exhausted after the hike	1	prime	I	N
The compliment made him proud	2	prime	I	E
She shook her head, not understanding	3	prime	E	N
He started to bite his nails in shame	4	prime	E	E
Contempt was showing on his face		TARGET	E	E
He was clenching his teeth furiously at the insult	1	prime	E	E
Suddenly she knew where to find it	2	prime	I	N
The funeral filled him with sorrow	3	prime	I	E
She crossed her legs when meditating	4	prime	E	N
He was ashamed and looked away		TARGET	E	E
She was eating the ice-cream that she craved	1	prime	E	N
Tears were running down his sad face	2	prime	E	E
She suddenly realized that she understood	3	prime	I	N
His heart rate went up because he was angry	4	prime	I	E
He fidgeted nervously in his chair		TARGET	E	E
He never felt so happy in his life	1	prime	I	E
She chews her lip because she couldn't find it	2	prime	E	N
He narrowed his eyes in hate	3	prime	E	E
She imagined being older	4	prime	I	N
He was pounding his fist on the table in anger		TARGET	E	E
Her muscles relaxed while she was meditating	1	prime	I	N
He was very disappointed after the game	2	prime	I	E
She dialled when the number came back to her	3	prime	E	N
His shoulders hung down with regret	4	prime	E	E
His facial expression betrayed his guilt		TARGET	E	E
His guilt made him buy flowers	1	prime	E	E
She thought she was going to faint	2	prime	I	N
He was so nervous he couldn't breathe.	3	prime	I	E
She inhaled sharply when she had the revelation	4	prime	E	N
Out of guilt he avoided eye contact		TARGET	E	E
She shook her head in doubt	1	prime	E	N
His face was pale with fear	2	prime	E	E
While meditating she visualized the sun	3	prime	I	N
Being at the party filled her with happiness	4	prime	I	E
He threw the paper down in disgust		TARGET	E	E
Her mouth went dry with fear	1	prime	I	E
He closed his eyes while meditating	2	prime	E	N
She smiled lovingly at her child	3	prime	E	E
He couldn't think because he was starving	4	prime	I	N

The praise made her beam with pride		TARGET	E	E
He experienced a sudden bolt of dizziness	1	prime	I	N
She was overcome with nausea	2	prime	I	E
He stroked his chin while thinking	3	prime	E	N
She hid her eyes because she was guilty	4	prime	E	E
Happiness made her twirl through the room		TARGET	E	E
The grieving mother cried loudly	1	prime	E	E
He was famished by the end of the race.	2	prime	I	N
Her stomach turned with nausea	3	prime	I	E
Starving, he wolfed down the pizza	4	prime	E	N
Her face was red with embarrassment		TARGET	E	E
Doubt made him stop in his tracks	1	prime	E	N
She jumped up because she was so proud	2	prime	E	E
He wondered what it would be like	3	prime	I	N
Excitement rushed into her	4	prime	I	E
Her cheeks were flushed with excitement		TARGET	E	E
Hot embarrassment came over her	1	prime	I	E
He sat down because he was dizzy	2	prime	E	N
She lowered her head with disappointment	3	prime	E	E
He tried to recollect the exact date	4	prime	I	N
Humiliated, she run out of the room		TARGET	E	E
His intuition told him not to go	1	prime	I	N
She was overcome with feelings of despair	2	prime	I	E
He scratched his head while remembering	3	prime	E	N
She looked away because she was guilty	4	prime	E	E
Her eyes were big with fear		TARGET	E	E
She had a look of triumph on her face	1	prime	E	E
He was lost in thought	2	prime	I	N
She loved her child deeply	3	prime	I	E
He yawned because he was tired	4	prime	E	N
Her face lit up with happiness		TARGET	E	E
The doubt was showing on his face	1	prime	E	N
Regret made her pull at her hair	2	prime	E	E
He visualized the route home	3	prime	I	N
Her triumph filled her with warmth	4	prime	I	E
She sighed with regret		TARGET	E	E
Guilt overwhelmed her when she found out	1	prime	I	E
He wrote down the answer	2	prime	E	N
She pulled her hair in despair	3	prime	E	E
On the building dizziness came over him	4	prime	I	N
Her face was distorted with rage		TARGET	E	E
He could not think because he was tired	1	prime	I	N
The distance between them made her sad	2	prime	I	E
Drawing the route helped him visualize	3	prime	E	N
She stopped eating because she was nauseous	4	prime	E	E
She frowned with anger at the injustice		TARGET	E	E
She cuddled her boyfriend	1	prime	E	E

He was overcome by confusion	2	prime	I	N
She almost choked with humiliation	3	prime	I	E
During meditation, his hands rested on his knees	4	prime	E	N
Her face was green with nausea		TARGET	E	E
His mouth fell open in confusion	1	prime	E	N
She kissed the boy she was in love with	2	prime	E	E
The remark puzzled him	3	prime	I	N
She had butterflies in her stomach, when she saw him	4	prime	I	E
Her sad eyes were wet with tears		TARGET	E	E
He loved his wife passionately	1	prime	I	E
Dizzily, she almost tripped	2	prime	E	N
He smiled because he was happy	3	prime	E	E
Her head was light with dizziness	4	prime	I	N
His face was distorted with grief		TARGET	E	E
Looking at the food made her hungry	2	prime	I	N
He was sick with disgust	3	prime	I	E
Her face was pale with exhaustion	4	prime	E	N
He waved his arms ecstatically	1	prime	E	E
After the lecture her mind was spinning		TARGET	I	N
His hands were shaking because he was terrified	2	prime	E	E
she was thinking deeply about the subject	3	prime	I	N
Guilt washed over him after he left	4	prime	I	E
She stopped, doubtful about where to go	1	prime	E	N
She was starting to doubt her assumptions		TARGET	I	N
She licked her lips because she was hungry	2	prime	E	N
Happily, he grinned from ear to ear	3	prime	E	E
During yoga tension left her body	4	prime	I	N
He was consumed by guilt	1	prime	I	E
Her thoughts were blurry from exhaustion		TARGET	I	N
He regretted missing the opportunity	2	prime	I	E
She gasped at the sense of deja vu	3	prime	E	N
He stared at the girl with desire	4	prime	E	E
She was puzzled by the sense of deja vu	1	prime	I	N
The image appeared in her mind		TARGET	I	N
The phone number came back to her in a flash	2	prime	I	N
He was burning with hate	3	prime	I	E
She stared blankly into space	4	prime	E	N
He looked around nervously	1	prime	E	E
She was craving ice-cream		TARGET	I	N
She was exhausted after the hike	2	prime	I	N
The compliment made him proud	3	prime	I	E
She shook her head, not understanding	4	prime	E	N
He started to bite his nails in shame	1	prime	E	E
She visualized the geometrical problem		TARGET	I	N
He was clenching his teeth furiously at the insult	2	prime	E	E

Suddenly she knew where to find it	3	prime	I	N
The funeral filled him with sorrow	4	prime	I	E
She crossed her legs when meditating	1	prime	E	N
Her mind went completely blank		TARGET	I	N
She was eating the ice-cream that she craved	2	prime	E	N
Tears were running down his sad face	3	prime	E	E
She suddenly realized that she understood	4	prime	I	N
His heart rate went up because he was angry	1	prime	I	E
Her limbs were heavy from exhaustion		TARGET	I	N
He never felt so happy in his life	2	prime	I	E
She chew her lip because she couldn't find it	3	prime	E	N
He narrowed his eyes in hate	4	prime	E	E
She imagined being older	1	prime	I	N
The revelation hit her		TARGET	I	N
Her muscles relaxed while she was meditating	2	prime	I	N
He was very disappointed after the game	3	prime	I	E
She dialled when the number came back to her	4	prime	E	N
His shoulders hung down with regret	1	prime	E	E
She emptied her mind in meditation		TARGET	I	N
His guilt made him buy flowers	2	prime	E	E
She thought she was going to faint	3	prime	I	N
He was so nervous he couldn't breathe.	4	prime	I	E
She inhaled sharply when she had the revelation	1	prime	E	N
The answer was on the tip of her tongue		TARGET	I	N
She shook her head in doubt	2	prime	E	N
His face was pale with fear	3	prime	E	E
While meditating she visualized the sun	4	prime	I	N
Being at the party filled her with happiness	1	prime	I	E
She was bewildered by what happened		TARGET	I	N
Her mouth went dry with fear	2	prime	I	E
He closed his eyes while meditating	3	prime	E	N
She smiled lovingly at her child	4	prime	E	E
He couldn't think because he was starving	1	prime	I	N
Doubt swirled in his head		TARGET	I	N
He experienced a sudden bolt of dizziness	2	prime	I	N
She was overcome with nausea	3	prime	I	E
He stroked his chin while thinking	4	prime	E	N
She hid her eyes because she was guilty	1	prime	E	E
A new idea formed in his mind		TARGET	I	N
The grieving mother cried loudly	2	prime	E	E
He was famished by the end of the race.	3	prime	I	N
Her stomach turned with nausea	4	prime	I	E
Starving, he wolfed down the pizza	1	prime	E	N
Confusion made his head spin		TARGET	I	N
Doubt made him stop in his tracks	2	prime	E	N
She jumped up because she was so proud	3	prime	E	E
He wondered what it would be like	4	prime	I	N

Excitement rushed into her	1	prime	I	E
He retrieved the memory from his mind		TARGET	I	N
Hot embarrassment came over her	2	prime	I	E
He sat down because he was dizzy	3	prime	E	N
She lowered her head with disappointment	4	prime	E	E
He tried to recollect the exact date	1	prime	I	N
He was faint with hunger		TARGET	I	N
His intuition told him not to go	2	prime	I	N
She was overcome with feelings of despair	3	prime	I	E
He scratched his head while remembering	4	prime	E	N
She looked away because she was guilty	1	prime	E	E
Intense fatigue came over him		TARGET	I	N
She had a look of triumph on her face	2	prime	E	E
He was lost in thought	3	prime	I	N
She loved her child deeply	4	prime	I	E
He yawned because he was tired	1	prime	E	N
He was in doubt about his decision		TARGET	I	N
The doubt was showing on his face	2	prime	E	N
Regret made her pull at her hair	3	prime	E	E
He visualized the route home	4	prime	I	N
Her triumph filled her with warmth	1	prime	I	E
His thoughts were thrown off by doubt		TARGET	I	N
Guilt overwhelmed her when she found out	2	prime	I	E
He wrote down the answer	3	prime	E	N
She pulled her hair in despair	4	prime	E	E
On the building dizziness came over him	1	prime	I	N
He searched his memory for the phone number		TARGET	I	N
He could not think because he was tired	2	prime	I	N
The distance between them made her sad	3	prime	I	E
Drawing the route helped him visualize	4	prime	E	N
She stopped eating because she was nauseous	1	prime	E	E
Suddenly he knew the answer		TARGET	I	N
She cuddled her boyfriend	2	prime	E	E
He was overcome by confusion	3	prime	I	N
She almost choked with humiliation	4	prime	I	E
During meditation, his hands rested on his knees	1	prime	E	N
Doubt filled his mind all day		TARGET	I	N
His mouth fell open in confusion	2	prime	E	N
She kissed the boy she was in love with	3	prime	E	E
The remark puzzled him	4	prime	I	N
She had butterflies in her stomach, when she saw him	1	prime	I	E
His skin tingled while meditating		TARGET	I	N
He loved his wife passionately	2	prime	I	E
Dizzily, she almost tripped	3	prime	E	N
He smiled because he was happy	4	prime	E	E
Her head was light with dizziness	1	prime	I	N

He listened to his intuition		TARGET	E	N
Looking at the food made her hungry	3	prime	I	N
He was sick with disgust	4	prime	I	E
Her face was pale with exhaustion	1	prime	E	N
He waved his arms ecstatically	2	prime	E	E
She looked bewildered		TARGET	E	N
His hands were shaking because he was terrified	3	prime	E	E
she was thinking deeply about the subject	4	prime	I	N
Guilt washed over him after he left	1	prime	I	E
She stopped, doubtful about where to go	2	prime	E	N
Exhausted, she rubbed her eyes		TARGET	E	N
She licked her lips because she was hungry	3	prime	E	N
Happily, he grinned from ear to ear	4	prime	E	E
During yoga tension left her body	1	prime	I	N
He was consumed by guilt	2	prime	I	E
Her body moved into a yoga position		TARGET	E	N
He regretted missing the opportunity	3	prime	I	E
She gasped at the sense of deja vu	4	prime	E	N
He stared at the girl with desire	1	prime	E	E
She was puzzled by the sense of deja vu	2	prime	I	N
While answering, she gestured		TARGET	E	N
The phone number came back to her in a flash	3	prime	I	N
He was burning with hate	4	prime	I	E
She stared blankly into space	1	prime	E	N
He looked around nervously	2	prime	E	E
The image made her stop talking		TARGET	E	N
She was exhausted after the hike	3	prime	I	N
The compliment made him proud	4	prime	I	E
She shook her head, not understanding	1	prime	E	N
He started to bite his nails in shame	2	prime	E	E
She meditated in the lotus position		TARGET	E	N
He was clenching his teeth furiously at the insult	3	prime	E	E
Suddenly she knew where to find it	4	prime	I	N
The funeral filled him with sorrow	1	prime	I	E
She crossed her legs when meditating	2	prime	E	N
She trembled with exhaustion		TARGET	E	N
She was eating the ice-cream that she craved	3	prime	E	N
Tears were running down his sad face	4	prime	E	E
She suddenly realized that she understood	1	prime	I	N
His heart rate went up because he was angry	2	prime	I	E
She sketched the solution she visualized		TARGET	E	N
He never felt so happy in his life	3	prime	I	E
She chew her lip because she couldn't find it	4	prime	E	N
He narrowed his eyes in hate	1	prime	E	E
She imagined being older	2	prime	I	N
She frowned when she was thinking		TARGET	E	N

Her muscles relaxed while she was meditating	3	prime	I	N
He was very disappointed after the game	4	prime	I	E
She dialled when the number came back to her	1	prime	E	N
His shoulders hung down with regret	2	prime	E	E
She tilted her head while imagining		TARGET	E	N
His guilt made him buy flowers	3	prime	E	E
She thought she was going to faint	4	prime	I	N
He was so nervous he couldn't breathe.	1	prime	I	E
She inhaled sharply when she had the revelation	2	prime	E	N
She held on to him, trying not to faint		TARGET	E	N
She shook her head in doubt	3	prime	E	N
His face was pale with fear	4	prime	E	E
While meditating she visualized the sun	1	prime	I	N
Being at the party filled her with happiness	2	prime	I	E
After spinning, she lost her balance		TARGET	E	N
Her mouth went dry with fear	3	prime	I	E
He closed his eyes while meditating	4	prime	E	N
She smiled lovingly at her child	1	prime	E	E
He couldn't think because he was starving	2	prime	I	N
His expression was one of confusion		TARGET	E	N
He experienced a sudden bolt of dizziness	3	prime	I	N
She was overcome with nausea	4	prime	I	E
He stroked his chin while thinking	1	prime	E	N
She hid her eyes because she was guilty	2	prime	E	E
He snapped his fingers when he remembered		TARGET	E	N
The grieving mother cried loudly	3	prime	E	E
He was famished by the end of the race.	4	prime	I	N
Her stomach turned with nausea	1	prime	I	E
Starving, he wolfed down the pizza	2	prime	E	N
Doubt made him pause mid-sentence		TARGET	E	N
Doubt made him stop in his tracks	3	prime	E	N
She jumped up because she was so proud	4	prime	E	E
He wondered what it would be like	1	prime	I	N
Excitement rushed into her	2	prime	I	E
His intuitive response was to walk away		TARGET	E	N
Hot embarrassment came over her	3	prime	I	E
He sat down because he was dizzy	4	prime	E	N
She lowered her head with disappointment	1	prime	E	E
He tried to recollect the exact date	2	prime	I	N
Famished, he gulped it down		TARGET	E	N
His intuition told him not to go	3	prime	I	N
She was overcome with feelings of despair	4	prime	I	E
He scratched his head while remembering	1	prime	E	N
She looked away because she was guilty	2	prime	E	E
He smacked his forehead when he had the idea		TARGET	E	N
She had a look of triumph on her face	3	prime	E	E

He was lost in thought	4	prime	I	N
She loved her child deeply	1	prime	I	E
He yawned because he was tired	2	prime	E	N
He shook his head because he couldn't remember		TARGET	E	N
The doubt was showing on his face	3	prime	E	N
Regret made her pull at her hair	4	prime	E	E
He visualized the route home	1	prime	I	N
Her triumph filled her with warmth	2	prime	I	E
He took a big hungry bite		TARGET	E	N
Guilt overwhelmed her when she found out	3	prime	I	E
He wrote down the answer	4	prime	E	N
She pulled her hair in despair	1	prime	E	E
On the building dizziness came over him	2	prime	I	N
He reached out for her, intuitively		TARGET	E	N
He could not think because he was tired	3	prime	I	N
The distance between them made her sad	4	prime	I	E
Drawing the route helped him visualize	1	prime	E	N
She stopped eating because she was nauseous	2	prime	E	E
He scratched his head in puzzlement		TARGET	E	N
She cuddled her boyfriend	3	prime	E	E
He was overcome by confusion	4	prime	I	N
She almost choked with humiliation	1	prime	I	E
During meditation, his hands rested on his knees	2	prime	E	N
He was swaying on his feet with dizziness		TARGET	E	N
His mouth fell open in confusion	3	prime	E	N
She kissed the boy she was in love with	4	prime	E	E
The remark puzzled him	1	prime	I	N
She had butterflies in her stomach, when she saw him	2	prime	I	E
He tapped his foot while wondering		TARGET	E	N
He loved his wife passionately	3	prime	I	E
Dizzily, she almost tripped	4	prime	E	N
He smiled because he was happy	1	prime	E	E
Her head was light with dizziness	2	prime	I	N
His eyes were red with fatigue		TARGET	E	N
Looking at the food made her hungry	4	prime	I	N
He was sick with disgust	1	prime	I	E
Her face was pale with exhaustion	2	prime	E	N
He waved his arms ecstatically	3	prime	E	E
He has been grieving since she passed away		TARGET	I	E
His hands were shaking because he was terrified	4	prime	E	E
She was thinking deeply about the subject	1	prime	I	N
Guilt washed over him after he left	2	prime	I	E
She stopped, doubtful about where to go	3	prime	E	N
He was hit by a pang of shame		TARGET	I	E
She licked her lips because she was hungry	4	prime	E	N

Happily, he grinned from ear to ear	1	prime	E	E
During yoga tension left her body	2	prime	I	N
He was consumed by guilt	3	prime	I	E
His nerves were out of control		TARGET	I	E
He regretted missing the opportunity	4	prime	I	E
She gasped at the sense of deja vu	1	prime	E	N
He stared at the girl with desire	2	prime	E	E
She was puzzled by the sense of deja vu	3	prime	I	N
Waves of embarrassment washed over him		TARGET	I	E
The phone number came back to her in a flash	4	prime	I	N
He was burning with hate	1	prime	I	E
She stared blankly into space	2	prime	E	N
He looked around nervously	3	prime	E	E
His guilt went to the pit of his stomach		TARGET	I	E
She was exhausted after the hike	4	prime	I	N
The compliment made him proud	1	prime	I	E
She shook her head, not understanding	2	prime	E	N
He started to bite his nails in shame	3	prime	E	E
He was furious because of the argument		TARGET	I	E
He was clenching his teeth furiously at the insult	4	prime	E	E
Suddenly she knew where to find it	1	prime	I	N
The funeral filled him with sorrow	2	prime	I	E
She crossed her legs when meditating	3	prime	E	N
He was overcome by desire		TARGET	I	E
She was eating the ice-cream that she craved	4	prime	E	N
Tears were running down his sad face	1	prime	E	E
She suddenly realized that she understood	2	prime	I	N
His heart rate went up because he was angry	3	prime	I	E
He was filled with shame because of the mistake		TARGET	I	E
He never felt so happy in his life	4	prime	I	E
She chew her lip because she couldn't find it	1	prime	E	N
He narrowed his eyes in hate	2	prime	E	E
She imagined being older	3	prime	I	N
Happiness gave him new energy		TARGET	I	E
Her muscles relaxed while she was meditating	4	prime	I	N
He was very disappointed after the game	1	prime	I	E
She dialled when the number came back to her	2	prime	E	N
His shoulders hung down with regret	3	prime	E	E
He was disgusted by the comment		TARGET	I	E
His guilt made him buy flowers	4	prime	E	E
She thought she was going to faint	1	prime	I	N
He was so nervous he couldn't breathe.	2	prime	I	E
She inhaled sharply when she had the revelation	3	prime	E	N
He was ecstatic because he won		TARGET	I	E
She shook her head in doubt	4	prime	E	N

His face was pale with fear	1	prime	E	E
While meditating she visualized the sun	2	prime	I	N
Being at the party filled her with happiness	3	prime	I	E
Contempt left a bitter taste in his mouth		TARGET	I	E
Her mouth went dry with fear	4	prime	I	E
He closed his eyes while meditating	1	prime	E	N
She smiled lovingly at her child	2	prime	E	E
He couldn't think because he was starving	3	prime	I	N
She was terrified of what might happen		TARGET	I	E
He experienced a sudden bolt of dizziness	4	prime	I	N
She was overcome with nausea	1	prime	I	E
He stroked his chin while thinking	2	prime	E	N
She hid her eyes because she was guilty	3	prime	E	E
She bubbled over with happiness		TARGET	I	E
The grieving mother cried loudly	4	prime	E	E
He was famished by the end of the race.	1	prime	I	N
Her stomach turned with nausea	2	prime	I	E
Starving, he wolfed down the pizza	3	prime	E	N
Seeing the images filled her with regret		TARGET	I	E
Doubt made him stop in his tracks	4	prime	E	N
She jumped up because she was so proud	1	prime	E	E
He wondered what it would be like	2	prime	I	N
Excitement rushed into her	3	prime	I	E
She was sad because he left		TARGET	I	E
Hot embarrassment came over her	4	prime	I	E
He sat down because he was dizzy	1	prime	E	N
She lowered her head with disappointment	2	prime	E	E
He tried to recollect the exact date	3	prime	I	N
Child labour made her angry		TARGET	I	E
His intuition told him not to go	4	prime	I	N
She was overcome with feelings of despair	1	prime	I	E
He scratched his head while remembering	2	prime	E	N
She looked away because she was guilty	3	prime	E	E
In her heart she knew she was guilty		TARGET	I	E
She had a look of triumph on her face	4	prime	E	E
He was lost in thought	1	prime	I	N
She loved her child deeply	2	prime	I	E
He yawned because he was tired	3	prime	E	N
She was so scared she was going crazy		TARGET	I	E
The doubt was showing on his face	4	prime	E	N
Regret made her pull at her hair	1	prime	E	E
He visualized the route home	2	prime	I	N
Her triumph filled her with warmth	3	prime	I	E
She was filled with pride after the interview		TARGET	I	E
Guilt overwhelmed her when she found out	4	prime	I	E
He wrote down the answer	1	prime	E	N
She pulled her hair in despair	2	prime	E	E
On the building dizziness came over him	3	prime	I	N

She suffered from regret after the decision		TARGET	I	E
He could not think because he was tired	4	prime	I	N
The distance between them made her sad	1	prime	I	E
Drawing the route helped him visualize	2	prime	E	N
She stopped eating because she was nauseous	3	prime	E	E
Pride made her lightheaded		TARGET	I	E
She cuddled her boyfriend	4	prime	E	E
He was overcome by confusion	1	prime	I	N
She almost choked with humiliation	2	prime	I	E
During meditation, his hands rested on his knees	3	prime	E	N
The injustice made her enraged		TARGET	I	E
His mouth fell open in confusion	4	prime	E	N
She kissed the boy she was in love with	1	prime	E	E
The remark puzzled him	2	prime	I	N
She had butterflies in her stomach, when she saw him	3	prime	I	E
She was madly in love with him		TARGET	I	E
He loved his wife passionately	4	prime	I	E
Dizzily, she almost tripped	1	prime	E	N
He smiled because he was happy	2	prime	E	E
Her head was light with dizziness	3	prime	I	N
She was heavy with disappointment		TARGET	I	E

Experiment 3: List of all stimuli

There were 2 groups. Group 1 saw sentences labelled 1 and Group 2 saw sentences labelled 2. They both saw the same target. E = emotion, C = Cognitive

Sentences	Type	Group	Emotionality
His voice trembled with embarrassment	prime	1	E
His voice trembled with uncertainty	prime	2	C
Her face was pale with fear	target		E
His voice trembled with uncertainty	prime	1	C
His voice trembled with embarrassment	prime	2	E
Her face was pale with confusion	target		C
He embraced his wife lovingly	prime	1	E
He thought about his wife while pacing	prime	2	C
She stopped, scared of where to go	target		E
He thought about his wife while pacing	prime	1	C
He embraced his wife lovingly	prime	2	E
She stopped, doubtful about where to go	target		C
He was ashamed and looked away	prime	1	E
He was thinking and looked around	prime	2	C
She bit her lips because she was angry	target		E
He was thinking and looked around	prime	1	C

He was ashamed and looked away	prime	2	E
She licked her lips because she was thinking	target		C
He fidgeted nervously	prime	1	E
He fidgeted while thinking	prime	2	C
She gasped at the sight of the ghost	target		E
He fidgeted while thinking	prime	1	C
He fidgeted nervously	prime	2	E
She gasped at the sense of deja vu	target		C
He was pounding his fist on the table in anger	prime	1	E
He was snapping his fingers when inspired	prime	2	C
She stared happily at the prize	target		E
He was snapping his fingers when inspired	prime	1	C
He was pounding his fist on the table in anger	prime	2	E
She stared blankly into space	target		C
His facial expression betrayed his guilt	prime	1	E
His facial expression exudes confident	prime	2	C
She shook her head, clearly not happy	target		E
His facial expression exudes confident	prime	1	C
His facial expression betrayed his guilt	prime	2	E
She shook her head, not understanding	target		C
Out of guilt he avoided eye contact	prime	1	E
Out of confusion, he looked puzzled	prime	2	C
She crossed her legs when she is anxious	target		E
Out of confusion, he looked puzzled	prime	1	C
Out of guilt he avoided eye contact	prime	2	E
She crossed her legs when meditating	target		C
He threw the paper down in disgust	prime	1	E
He threw the paper accurately	prime	2	C
She was frightened at the sight of the man	target		E
He threw the paper accurately	prime	1	C
He threw the paper down in disgust	prime	2	E
She was eating the ice-cream that she craved	target		C
The praise made her beam with pride	prime	1	E
The suggestion made her beam with confidence	prime	2	C
She chewed her lip because she angry	target		E
The suggestion made her beam with confidence	prime	1	C
The praise made her beam with pride	prime	2	E
She chewed her lip because she lost in thoughts	target		C
Regret made her pull at her hair	prime	1	E
Solving the puzzle made her head hurts	prime	2	C
Doubt made him pause mid-sentence	target		C
Solving the puzzle made her head hurts	prime	1	C
Regret made her pull at her hair	prime	2	E
Fear made him pause mid-sentence	target		E
She pulled her hair in despair	prime	1	E
She tied her hair while thinking	prime	2	C

His intuitive response was to walk away	target		C
She tied her hair while thinking	prime	1	C
She pulled her hair in despair	prime	2	E
His intuitive response was to cry	target		E
She stopped eating because she was nauseous	prime	1	E
She stopped thinking because she was tired	prime	2	C
He smacked his forehead when he had the idea	target		C
She stopped thinking because she was tired	prime	1	C
She stopped eating because she was nauseous	prime	2	E
He slammed his tabled when he was furious	target		E
She cuddled with her boyfriend	prime	1	E
She meditated with her teacher	prime	2	C
He shook his head because he couldn't remember	target		C
She meditated with her teacher	prime	1	C
She cuddled with her boyfriend	prime	2	E
He shook his head because he couldn't cry	target		E
She kissed the boy she was in love with	prime	1	E
She looked at the boy that she was thinking about	prime	2	C
He yelled out his answer after much thinking	target		C
She looked at the boy that she was thinking about	prime	1	C
She kissed the boy she was in love with	prime	2	E
He yelled in an angry tone	target		E
He smiled because he was happy	prime	1	E
He sighed because he was fatigued	prime	2	C
He reached out for her, intuitively	target		C
He sighed because he was fatigued	prime	1	C
He smiled because he was happy	prime	2	E
He smiled at her, happily	target		E
His face showed disgust	prime	1	E
His face showed utmost concentration	prime	2	C
He scratched his head in puzzlement	target		C
His face showed utmost concentration	prime	1	C
His face showed disgust	prime	2	E
He scratched his head in distress	target		E
Guilt was visible on his face after he left	prime	1	E
Curiosity was visible on his face after he left	prime	2	C
He was swaying on his feet with dizziness	target		C
Curiosity was visible on his face after he left	prime	1	C
Guilt was visible on his face after he left	prime	2	E
He was swaying on his feet with joy	target		E
He was running away from his guilt	prime	1	E
He was running away from his thoughts	prime	2	C
He tapped his foot while wondering	target		C
He was running away from his thoughts	prime	1	C
He was running away from his guilt	prime	2	E
He tapped his foot while anxious	target		E

Happiness made her twirl through the room	prime	1	E
Confusion made her pace around the room	prime	2	C
She dialled her partner when she was happy	target		E
Confusion made her pace around the room	prime	1	C
Happiness made her twirl through the room	prime	2	E
She dialled when the number came back to her	target		C
Her face was red with embarrassment	prime	1	E
Her face was red with dizziness	prime	2	C
She inhaled sharply when she was furious	target		E
Her face was red with dizziness	prime	1	C
Her face was red with embarrassment	prime	2	E
She inhaled sharply when she had the revelation	target		C
Her cheeks were flushed with excitement	prime	1	E
Her cheeks were flushed due to exhaustion	prime	2	C
She shook her head in anger	target		E
Her cheeks were flushed due to exhaustion	prime	1	C
Her cheeks were flushed with excitement	prime	2	E
She shook her head in doubt	target		C
Humiliated, she ran out of the room	prime	1	E
Thinking, she paced around the room	prime	2	C
He closed his eyes out of fear	target		E
Thinking, she paced around the room	prime	1	C
Humiliated, she ran out of the room	prime	2	E
He closed his eyes while meditating	target		C
Her eyes were big with fear	prime	1	E
Her eyes were big with anticipation	prime	2	C
He stroked his chin while smiling happily	target		E
Her eyes were big with anticipation	prime	1	C
Her eyes were big with fear	prime	2	E
He stroked his chin while thinking	target		C
Her face was distorted with rage	prime	1	E
Her face was distorted with dizziness	prime	2	C
Fear made him stop in his tracks	target		E
Her face was distorted with dizziness	prime	1	C
Her face was distorted with rage	prime	2	E
Doubt made him stop in his tracks	target		C
She frowned with anger at the injustice	prime	1	E
She frowned thinking about the past	prime	2	C
He sat down because he was sad	target		E
She frowned thinking about the past	prime	1	C
She frowned with anger at the injustice	prime	2	E
He sat down because he was dizzy	target		C
Her face was green with nausea	prime	1	E
Her eye shifted when she was lying	prime	2	C
He held his head because he was scared	target		E
Her eye shifted when she was lying	prime	1	C

Her face was green with nausea	prime	2	E
He scratched his head while remembering	target		C
Her sad eyes were wet with tears	prime	1	E
Her closed eyes were signalling her deep thoughts	prime	2	C
He jumped because he was shocked	target		E
Her closed eyes were signalling her deep thoughts	prime	1	C
Her sad eyes were wet with tears	prime	2	E
He stood still because he was thinking	target		C
His body sunk onto the couch due to sadness	prime	1	E
His body sunk onto the couch due to confusion	prime	2	C
His eyes were red with fatigue	target		C
His body sunk onto the couch due to confusion	prime	1	C
His body sunk onto the couch due to sadness	prime	2	E
His eyes were red with anger	target		E
He was stomping the ground with anger	prime	1	E
He was standing still in puzzlement	prime	2	C
Her stomach growled as she was hungry	target		C
He was standing still in puzzlement	prime	1	C
He was stomping the ground with anger	prime	2	E
Her eyes twitched when she was angry	target		E
The compliment made her cry tears of joy	prime	1	E
The podcast made her sigh in disbelief	prime	2	C
She closed her eyes while thinking deeply	target		C
The podcast made her sigh in disbelief	prime	1	C
The compliment made her cry tears of joy	prime	2	E
She closed her eyes as she was scared	target		E
The funeral was very sad he stood there silently	prime	1	E
The event was very informative he stood there silently thinking	prime	2	C
During yoga, her body was still and calm	target		C
The event was very informative he stood there silently thinking	prime	1	C
The funeral was very sad he stood there silently	prime	2	E
During the panic, her body stifled	target		E
He scratched his head in despair	prime	1	E
He scratched his head in confusion	prime	2	C
She stopped in her tracks when she had a deja vu	target		C
He scratched his head in confusion	prime	1	C
He scratched his head in despair	prime	2	E
She stopped in her tracks when she had a fright	target		E
He breathed heavily because he failed	prime	1	E
He breathed calmly when he was focusing	prime	2	C
He rubbed his temple trying to remember his phone number	target		C
He breathed calmly when he was focusing	prime	1	C
He breathed heavily because he failed	prime	2	E
He rubbed his temple trying to contain his anger	target		E

He jumped giddily when he won	prime	1	E
He leaned forward when he was concentrating	prime	2	C
She was gasping for air after the hike	target		C
He leaned forward when he was concentrating	prime	1	C
He jumped giddily when he won	prime	2	E
She was gasping for air after the anxiety attack	target		E
He was sighing heavily after his failure	prime	1	E
He was gesturing slowly to convey his ideas	prime	2	C
She was wobbly when she was dizzy	target		C
He was gesturing slowly to convey his ideas	prime	1	C
He was sighing heavily after his failure	prime	2	E
She was wobbly when she was in distress	target		E
He was so nervous he froze in place	prime	1	E
He was still meditating he sat still in place	prime	2	C
She shouted when she thought of a great idea	target		C
He was still meditating he sat still in place	prime	1	C
He was so nervous he froze in place	prime	2	E
She shouted when she saw a big bug	target		E
He was dancing happily at the party	prime	1	E
He was shaking off his confusion	prime	2	C
She sat down quietly when she was imagining	target		C
He was shaking off his confusion	prime	1	C
He was dancing happily at the party	prime	2	E
She sat down anxiously when she was waiting	target		E
Her mouth went dry with fear	prime	1	E
Her mouth went dry with disbelief	prime	2	C
Her facial expression looked calm when she was meditating	target		C
His face was distorted with grief	prime	1	E
His face was distorted with confusion	prime	2	C
The happiness was showing on his face	target		E
His face was distorted with confusion	prime	1	C
His face was distorted with grief	prime	2	E
The doubt was showing on his face	target		C
He waved his arms ecstatically	prime	1	E
He waved his arms in confusion	prime	2	C
He wrote down his true feelings	target		E
He waved his arms in confusion	prime	1	C
He waved his arms ecstatically	prime	2	E
He wrote down the answer	target		C
His hands were shaking because he was terrified	prime	1	E
His hands were still as he was calm	prime	2	C
Drawing the picture made him happy	target		E
His hands were still as he was calm	prime	1	C
His hands were shaking because he was terrified	prime	2	E
Drawing the route helped him visualize	target		C

Happily, he grinned from ear to ear	prime	1	E
Suddenly, he sat down thinking	prime	2	C
During exam, his hands shivers with anxiety	target		E
Suddenly, he sat down thinking	prime	1	C
Happily, he grinned from ear to ear	prime	2	E
During meditation, his hands rested on his knees	target		C
He stared at the girl with desire	prime	1	E
He stared at the girl inquisitively	prime	2	C
His mouth fell open in shock	target		E
He stared at the girl inquisitively	prime	1	C
He stared at the girl with desire	prime	2	E
His mouth fell open in confusion	target		C
He looked around nervously	prime	1	E
He looked around aimlessly	prime	2	C
Happily, she jumped around	target		E
He looked around aimlessly	prime	1	C
He looked around nervously	prime	2	E
Dizzily, she almost tripped	target		C
He started to bite his nails in shame	prime	1	E
He started to fall asleep due to exhaustion	prime	2	C
She looked happy	target		E
He started to fall asleep due to exhaustion	prime	1	C
He started to bite his nails in shame	prime	2	E
She looked bewildered	target		C
He was clenching his teeth furiously at the insult	prime	1	E
He was clenching his teeth trying to solve the problem	prime	2	C
Shocked, she rubbed her eyes	target		E
He was clenching his teeth trying to solve the problem	prime	1	C
He was clenching his teeth furiously at the insult	prime	2	E
Exhausted, she rubbed her eyes	target		C
Tears were running down his sad face	prime	1	E
Sweats were running down his tired face	prime	2	C
Her body shivers from the fear	target		E
Sweats were running down his tired face	prime	1	C
Tears were running down his sad face	prime	2	E
Her body moved into a yoga position	target		C
He narrowed his eyes in hatred	prime	1	E
He narrowed his eyes in confusion	prime	2	C
While talking, she stuttered due to stage fright	target		E
Her mouth went dry with disbelief	prime	1	C
Her mouth went dry with fear	prime	2	E
Her facial expression looked pale when she saw the corpse	target		E
She was holding her mouth due to nausea	prime	1	E
She was holding her mouth due to dizziness	prime	2	C

She held the wall when she thought that she was going to faint	target		C
She was holding her mouth due to dizziness	prime	1	C
She was holding her mouth due to nausea	prime	2	E
The held the wall when she was disgusted	target		E
She cowered at the corner of the room after being scared	prime	1	E
She sat at the corner of the room after being confused	prime	2	C
While meditating, she breathes calmly	target		C
She sat at the corner of the room after being confused	prime	1	C
She cowered at the corner of the room after being scared	prime	2	E
While singing, she smiles brightly	target		E
Excited, she could not sit still	prime	1	E
Dizzy, she could not stand still	prime	2	C
He was holding his stomach because of certain memories	target		C
Dizzy, she could not stand still	prime	1	C
Excited, she could not sit still	prime	2	E
He was holding his stomach because he was disgusted	target		E
She closed her eyes due to her embarrassment	prime	1	E
She closed her eyes while imagining the picture	prime	2	C
His body experienced a sudden jolt when he woke up	target		C
She closed her eyes while imagining the picture	prime	1	C
She closed her eyes due to her embarrassment	prime	2	E
His body experienced a sudden jolt when he was shocked	target		E
She hung her head down in despair	prime	1	E
She hung her head down while thinking deeply	prime	2	C
He was walking slowly when he remembered his past	target		C
She hung her head down while thinking deeply	prime	1	C
She hung her head down in despair	prime	2	E
He was walking quickly after watching the scary movie	target		E
She smiled at her child endearingly	prime	1	E
She talked with her friend thoughtfully	prime	2	C
He scratched his head while wondering	target		C
She talked with her friend thoughtfully	prime	1	C
She smiled at her child endearingly	prime	2	E
He turned his head away from the disgusting scene	target		E
Her triumphant victory made her jump with joy	prime	1	E
Her habit to rub her chin while thinking was unique	prime	2	C
He rubbed his chin to recollect the exact date	target		C
Her habit to rub her chin while thinking was unique	prime	1	C
Her triumphant victory made her jump with joy	prime	2	E
He muttered some curses quietly to quell his anger	target		E
Her guilt made her stutter during the trials	prime	1	E
Her confusion causes her to get lost during the hike	prime	2	C

His keen intuition made him walk carefully	target		C
Her confusion causes her to get lost during the hike	prime	1	C
Her guilt made her stutter during the trials	prime	2	E
His anxious nature made him walk carefully	target		E
Her sadness cause tears to well up in her eyes	prime	1	E
Her confusion caused her to sweat	prime	2	C
He walked aimlessly when he was confused	target		C
He narrowed his eyes in confusion	prime	1	C
He narrowed his eyes in hatred	prime	2	E
While answering, she gestured accurately to the audience	target		C
His shoulders hung down with regret	prime	1	E
His shoulders stiffened when he meditates	prime	2	C
The image made her stop smiling	target		E
His shoulders stiffened when he meditates	prime	1	C
His shoulders hung down with regret	prime	2	E
The image made her stop talking	target		C
His guilt made him buy flowers	prime	1	E
His confidence made him buy a ring	prime	2	C
She talked in low voice due to fear	target		E
His confidence made him buy a ring	prime	1	C
His guilt made him buy flowers	prime	2	E
She talked in low voice as she was meditating	target		C
She smiled lovingly at her child	prime	1	E
She thought about at her child's past	prime	2	C
She sketched her future plan happily	target		E
She thought about at her child's past	prime	1	C
She smiled lovingly at her child	prime	2	E
She sketched the solution she visualized	target		C
She hid her eyes because she was guilty	prime	1	E
She hid her eyes because she was shy	prime	2	C
She frowned when she was sad	target		E
She hid her eyes because she was shy	prime	1	C
She hid her eyes because she was guilty	prime	2	E
She sighed when she was thinking	target		C
The grieving mother cried loudly	prime	1	E
The gentle mother sang proudly	prime	2	C
She reeled her head in disgust	target		E
The gentle mother sang proudly	prime	1	C
The grieving mother cried loudly	prime	2	E
She tilted her head while imagining	target		C
She jumped up because she was so proud	prime	1	E
She sat down because she was so tired	prime	2	C
She held on to him, happy and not letting go	target		E
She sat down because she was so tired	prime	1	C
She jumped up because she was so proud	prime	2	E

She held on to him, trying not to faint	target		C
She lowered her head with disappointment	prime	1	E
She lowered her head with respect	prime	2	C
After reading, she lost her composure and cry	target		E
She lowered her head with respect	prime	1	C
She lowered her head with disappointment	prime	2	E
After spinning, she lost her balance and fell	target		C
She looked away because she was guilty	prime	1	E
She looked away because she was dizzy	prime	2	C
His expression was one of anger	target		E
She looked away because she was dizzy	prime	1	C
She looked away because she was guilty	prime	2	E
His expression was one of confusion	target		C
She had a look of triumph on her face	prime	1	E
She had a look of curiosity on her face	prime	2	C
He snapped his pencil when he was enraged	target		E
She had a look of pure curiosity on her face	prime	1	C
She had a look of triumph on her face	prime	2	E
He snapped his fingers when he remembered	target		C
Her confusion caused her to sweat	prime	1	C
Her sadness cause tears to well up in her eyes	prime	2	E
He walked confidently when he was happy	target		E
She held her skirt down when she was humiliated	prime	1	E
She held her head down when she was perplexed	prime	2	C
He furrowed his brows when he was thinking of a solution	target		C
She held her head down when she was perplexed	prime	1	C
She held her skirt down when she was humiliated	prime	2	E
He furrowed his brows when he was furious	target		E
When she was nervous, she talked slowly	prime	1	E
When she was meditating, she breathes calmly	prime	2	C
His eyes darted around when he was thinking	target		C
When she was meditating, she breathes calmly	prime	1	C
When she was nervous, she talked slowly	prime	2	E
His eyes turn white when he saw the tiger	target		E
She hid her face when she was grieving	prime	1	E
She hid her face when she was bewildered	prime	2	C
After the lecture, he was cradling his head, confused	target		C
She hid her face when she was bewildered	prime	1	C
She hid her face when she was grieving	prime	2	E
After the insult, he was shouting, enraged	target		E
He was so nervous he started to sweat	prime	1	E
He was so confident he started to puff his chest	prime	2	C
Her face was showing signs of bewilderment	target		C
He was so confident he started to puff his chest	prime	1	C
He was so nervous he started to sweat	prime	2	E

Her face was showing signs of anger	target		E
Embarrassed, he was smiling awkwardly	prime	1	E
Confused, he was sighing loudly	prime	2	C
His eyes opened wide when he got the answer	target		C
Confused, he was sighing loudly	prime	1	C
Embarrassed, he was smiling awkwardly	prime	2	E
His eyes opened wide when he got shocked	target		E
Her heartbeat was loud during the horror movie	prime	1	E
Her body was still during the meditation	prime	2	C
Her stomach rumbled when she was thinking of food	target		C
Her body was still during the meditation	prime	1	C
Her heartbeat was loud during the horror movie	prime	2	E
Her body jerked when she was surprised	target		E
Her smile shows signs of elation	prime	1	E
Her poker face shows no sign of thoughts	prime	2	C
She gestured the answer for the geometrical problem	target		C
Her poker face shows no sign of thoughts	prime	1	C
Her smile shows signs of elation	prime	2	E
She ripped the paper since she was mad	target		E

Chapter 3: Cumulative Semantic Interference

Experiment 1

Pictures in each category.

Emotions	Vehicles	Instruments	Birds
anger	Car	Guitar	Peacock
disgust	Tractor	Banjo	Eagle
fear	Boat	Cello	Ostrich
happiness	Plane	Clarinet	Penguin
sadness	Bicycle	Trumpet	Duck
surprise	Bus	Piano	Pigeon
contempt	Truck	Keyboard	Owl
neutral	Jeep	Drum	Hen

Order of pictures in unrelated block

Cycle	First Block	Second block	Third block	Fourth block
1	Anger	Car	Guitar	Peacock
2	Tractor	Banjo	Eagle	Disgust
3	Cello	Ostrich	Fear	Boat
4	Penguin	Happiness	Plane	Clarinet
1	Tractor	Banjo	Eagle	Disgust
2	Cello	Ostrich	Fear	Boat
3	Penguin	Happiness	Plane	Clarinet
4	Anger	Car	Guitar	Peacock
1	Cello	Ostrich	Fear	Boat
2	Penguin	Happiness	Plane	Clarinet
3	Anger	Car	Guitar	Peacock
4	Tractor	Banjo	Eagle	Disgust
1	Penguin	Happiness	Plane	Clarinet
2	Anger	Car	Guitar	Peacock
3	Tractor	Banjo	Eagle	Disgust
4	Cello	Ostrich	Fear	Boat

Cycle	Fifth block	Sixth block	Seventh Block	Eighth block
1	Sadness	Bicycle	Trumpet	Duck
2	Bus	Piano	Pigeon	Surprise
3	Keyboard	Owl	Contempt	Truck
4	Hen	Neutral	Jeep	Tambourine

1	Bus	Piano	Pigeon	Surprise
2	Cello	Owl	Contempt	Truck
3	Penguin	Neutral	Jeep	Tambourine
4	sadness	Bicycle	Trumpet	Duck
1	Cello	Owl	Contempt	Truck
2	Penguin	Neutral	Jeep	Tambourine
3	sadness	Bicycle	Trumpet	Duck
4	Bus	Piano	Pigeon	Surprise
1	Penguin	Neutral	Jeep	Tambourine
2	sadness	Bicycle	Trumpet	Duck
3	Bus	Piano	Pigeon	Surprise
4	Cello	Owl	Contempt	Truck

Order of pictures in related block

Cycle	Emotions	Vehicles	Utensils	Birds
1	anger	Car	Guitar	Peacock
2	disgust	Tractor	Banjo	Eagle
3	fear	Boat	Cello	Ostrich
4	happiness	Plane	Clarinet	Penguin
1	disgust	Tractor	Banjo	Eagle
2	fear	Boat	Cello	Ostrich
3	happiness	Plane	Clarinet	Penguin
4	anger	Car	Guitar	Peacock
1	fear	Boat	Cello	Ostrich
2	happiness	Plane	Clarinet	Penguin
3	anger	Car	Guitar	Peacock
4	disgust	Tractor	Banjo	Eagle
1	happiness	Plane	Clarinet	Penguin
2	anger	Car	Guitar	Peacock
3	disgust	Tractor	Banjo	Eagle
4	fear	Boat	Cello	Ostrich

Cycle	emotions	Vehicles	Utensils	Birds
1	Sadness	Bicycle	Trumpet	Duck

2	surprise	Bus	Piano	Pigeon
3	contempt	Truck	Keyboard	Owl
4	neutral	Jeep	Tambourine	Hen
1	surprise	Bus	Piano	Pigeon
2	contempt	Truck	Keyboard	Owl
3	neutral	Jeep	Tambourine	Penguin
4	sadness	Bicycle	Trumpet	Hen
1	contempt	Truck	Keyboard	Owl
2	neutral	Jeep	Tambourine	Penguin
3	sadness	Bicycle	Trumpet	Hen
4	surprise	Bus	Piano	Pigeon
1	neutral	Jeep	Tambourine	Penguin
2	sadness	Bicycle	Trumpet	Hen
3	surprise	Bus	Piano	Pigeon
4	contempt	Truck	Keyboard	Owl

Alternatives names

	Items	**Alternative**
1	bicycle	bike
2	bus	coach
3	cello	violin
4	cello	chello
5	clarinet	flute
6	hen	chicken
7	fear	fearful
8	fear	scared
9	disgust	disgusted
10	angry	anger
11	contempt	contemptuous
12	sad	sadness
13	surprise	surprised
14	surprise	shocked
15	drum	drums
16	happy	happiness
17	truck	lorry

Experiment 2

Pictures in each category obtained from Open Affective Standardised Image set (OASIS; Kurdi et al., 2017).

Categories	Positive	Negative	Neutral1	Neutral2
Aquatic animal	Penguins 2	Shark 4	Seal 1	Stingray 3
Nature phenomenon	Rainbow 1	Tornado 1	Thunderstorm 10	Snow 2
Landscape	Fireworks 2	Cemetery 4	City 1	Street 5
Mammals	Puppy 6	Ferret 1	Bear 2	Pig 1

Order of pictures in unrelated block

Cycle	First Block	Second block	Third block	Fourth block
1	Penguins 2	Shark 4	Seal 1	Stingray 3
2	Tornado 1	Thunderstorm 10	Snow 2	Rainbow 1
3	City 1	Street 5	Fireworks 2	Cemetery 4
4	Pig 1	Puppy 6	Ferret 1	Bear 2
1	Tornado 1	Thunderstorm 10	Snow 2	Rainbow 1
2	City 1	Street 5	Fireworks 2	Cemetery 4
3	Pig 1	Puppy 6	Ferret 1	Bear 2
4	Penguins 2	Shark 4	Seal 1	Stingray 3
1	City 1	Street 5	Fireworks 2	Cemetery 4
2	Pig 1	Puppy 6	Ferret 1	Bear 2
3	Penguins 2	Shark 4	Seal 1	Stingray 3
4	Tornado 1	Thunderstorm 10	Snow 2	Rainbow 1
1	Pig 1	Puppy 6	Ferret 1	Bear 2
2	Penguins 2	Shark 4	Seal 1	Stingray 3
3	Tornado 1	Thunderstorm 10	Snow 2	Rainbow 1
4	City 1	Street 5	Fireworks 2	Cemetery 4

Order of pictures in related block

Cycle	Positive	Negative	Neutral	Neutral1
1	Penguins 2	Shark 4	Seal 1	Stingray 3
2	Rainbow 1	Tornado 1	Thunderstorm 10	Snow 2
3	Fireworks 2	Cemetery 4	City 1	Street 5
4	Puppy 6	Ferret 1	Bear 2	Pig 1
1	Rainbow 1	Tornado 1	Thunderstorm 10	Snow 2
2	Fireworks 2	Cemetery 4	City 1	Street 5
3	Puppy 6	Ferret 1	Bear 2	Pig 1
4	Penguins 2	Shark 4	Seal 1	Stingray 3
1	Fireworks 2	Cemetery 4	City 1	Street 5

2	Puppy 6	Ferret 1	Bear 2	Pig 1
3	Penguins 2	Shark 4	Seal 1	Stingray 3
4	Rainbow 1	Tornado 1	Thunderstorm 10	Snow 2
1	Puppy 6	Ferret 1	Bear 2	Pig 1
2	Penguins 2	Shark 4	Seal 1	Stingray 3
3	Rainbow 1	Tornado 1	Thunderstorm 10	Snow 2
4	Fireworks 2	Cemetery 4	City 1	Street 5

Alternative names

	Items	Alternatives
1	seal	seals
2	cemetery	cemetary
3	ferret	feret
4	fireworks	firework
5	penguins	penguin

Chapter 4: Visual World Paradigm

List of sentences

Sentence	Emotion	Target	Competitor	Distractor	Distractor2
At the park, the kid was sad when the wind blew his favourite hat	Negative	hat	kite	boot	cheese
At the park, the kid was happy when the wind blew his favourite kite	Positive	kite	hat	boot	cheese
During the performance, the singer was dejected when her audience threw a bunch of tomatoes	Negative	tomatoes	roses	dogs	dentist
During the performance, the singer was happy when her audience threw a bunch of roses	Positive	roses	tomatoes	dogs	dentist
For her birthday, the ballet dancer was disappointed when she received a new drumstick	Negative	drumsticks	tutu	pie	vegetables
For her birthday, the ballet dancer was pleased when she receives a new tutu	Positive	tutu	drumsticks	pie	vegetables
In the kitchen during rush hour, the cook was relieved when he finds the hidden pot	Positive	pot	rat	building	mailman
In the kitchen during rush hour, the cook was shocked when he finds a hidden rat	Negative	rat	pot	building	mailman
On Valentines, the girl was sad when she receives the unexpected socks	Negative	socks	chocolate	log	train
On Valentines, the girl was happy when she receives the unexpected chocolate	Positive	chocolate	socks	log	train
The amateur fisherman was disgusted when his assistant lends him a bucket full of live worms	Negative	worms	fishes	cats	hats
The amateur fisherman was elated when his	Positive	fishes	worms	cats	hats

assistant lends him a bucket full of live fishes					
The basketballer was mad when the ball went into the drain	Negative	drain	basket	wheel	toys
The basketballer was pleased when the ball went into the basket	Positive	basket	drain	wheel	toys
The boy was elated when he kicked the side of the ball	Positive	ball	chair	basket	hand
The boy was in pain when he kicked the side of the chair	Negative	chair	ball	basket	hand
The child was scared when he visited the local dentist	Negative	dentist	wheel	book	face
The child was excited when he visited the local Ferris wheel	Positive	wheel	dentist	book	face
The couple were happy when they feed the docile rabbit	Positive	rabbit	tiger	snack	train
The couple were scared when they feed the docile tiger	Negative	tiger	rabbit	snack	train
The customer was happy when she was served the expensive dessert	Positive	dessert	bill	book	face
The customer was disappointed when she received the expensive bill	Negative	bill	dessert	book	face
The diner was pleased when her cake contains an unexpected strawberry	Positive	strawberry	fly	axe	socks
The diner was disgusted when her cake contains an unexpected fly	Negative	fly	strawberry	axe	socks
The dog was scared when the owner brought him to the local veterinarian	Negative	veterinarian	park	goalpost	mole
The dog was happy when the owner brought him to the local park	Positive	park	veterinarian	goalpost	mole
The faint-hearted child was happy when he rode the busy carousel	Positive	carousel	coaster	dessert	hotel
The faint-hearted child was scared when he	Negative	coaster	carousel	dessert	hotel

rode the busy roller coaster					
The farmer was mad when he found a big mole	Negative	mole	carrot	book	hand
The farmer was happy when he found a big carrot	Positive	carrot	mole	book	hand
The fisherman was angry when he caught a large boot	Negative	boot	fish	hair	manhole
The fisherman was happy when he caught a large fish	Positive	fish	boot	hair	manhole
The gardener was disgusted when he accidentally touched a small worm	Negative	worm	rabbit	onion	rose
The gardener was happy when he accidentally touched a small rabbit	Positive	rabbit	worm	onion	rose
The girl was disgusted when her baked potatoes were covered by a lot of hair	Negative	hair	cheese	rose	cat
The girl was happy when her baked potatoes were covered by a lot of cheese	Positive	cheese	hair	rose	cat
The girl was hurt when she managed to cut her small finger	Negative	finger	cat	dog	receipt
The girl was pleased when she saw a small cat	Positive	cat	finger	knife	strawberries
The girl was satisfied when she managed to cut her small onion	Positive	onion	spider	dog	receipt
The girl was shocked when she saw a small spider	Negative	spider	onion	knife	strawberries
The grandfather was dejected when the people knocking on the door turns out to be his dutiful mailman	Negative	mailman	family	books	target
The grandfather was pleased when the people knocking on the door turns out to be his dutiful family	Positive	family	mailman	books	target
The hikers were amazed by the scene of the sudden river	Positive	river	bear	policeman	veterinarian

The hikers were frightened by the scene of the sudden bear	Negative	bear	river	policeman	veterinarian
The hikers were happy when they saw a large deer	Positive	deer	bear2	cheese	hat
The hikers were scared when they saw a large bear	Negative	bear2	deer	cheese	hat
The lady was scared when she saw a running cockroach	Negative	cockroach	puppy	chocolate	pot
The lady was pleased when she saw a running puppy	Positive	puppy	cockroach	chocolate	pot
The little boy was sad when he found out that his lunch contains some vegetables	Negative	vegetables	chocolate	rock	tree
The little boy was happy when he ate a piece of chocolate	Positive	chocolate	vegetables	Lego	log
The little boy was upset when he ate a piece of broccoli	Negative	broccoli	chicken	Lego	log
The little boy was happy when he found out that his lunch contains some chicken	Positive	chicken	broccoli	rock	tree
The logger was overjoyed when he broke the sturdy tree	Positive	tree	axe	drumsticks	puppy
The logger was sad when he broke the sturdy axe	Negative	axe	tree	drumsticks	puppy
The man was pleased when he hit the stationary target	Positive	target	dog	wheel	flowers
The man was displeased when he hit the stationary dog	Negative	dog	target	wheel	flowers
The mechanic was disappointed when he finally found his missing receipts	Negative	dues	spanner	pie	tutu
The mechanic was happy when he finally found his missing spanner	Positive	spanner	dues	pie	tutu
The mother was happy when her baby was playing with the new Lego	Positive	Lego	knife	foot	strawberry
The mother was scared when her baby was	Negative	knife	Lego	foot	strawberry

playing with the new knife					
The musician was sad when he received a pair of socks	Negative	socks	drumsticks	car	receipt
The musician was happy when he receives a pair of drumsticks	Positive	drumsticks	socks	car	receipt
The robber was annoyed when he lost the big TV	Negative	TV	policeman	kite	park
The robber was pleased when he lost the big policeman	Positive	policeman	TV	kite	park
The shopper was sad when she was brought to the massive cemetery	Negative	cemetery	mall	family	tomatoes
The shopper was happy when she was brought to the massive mall	Positive	mall	cemetery	family	tomatoes
The student was pleased to have finished her collection of books	Positive	books	snacks	bills	carousel
The student was sad to have finished her collection of snacks	Negative	snacks	books	bills	carousel
The teenager was sad when her parents told her to eat her bowl of vegetables	Negative	vegetables	cream	cat	hand
The teenager was happy when her parents told her to eat her bowl of ice-cream	Positive	ice-cream	vegetables	cat	hand
The traveller was scared when he saw the big cemetery	Negative	cemetery	station	roses	chocolate
The traveller was relieved when he saw the big petrol station	Positive	station	cemetery	roses	chocolate
The woman was relieved when she missed the fast car	Positive	car	train	vegetables	broccoli
The woman was annoyed when she missed the fast train	Negative	train	car	vegetables	broccoli
The young boy was ecstatic because his cupcake contains a large chocolate	Positive	chocolate	fly	knife	spanner
The young boy was mad because his cupcake contains a large fly	Negative	fly	chocolate	knife	spanner

At the park, the kid was sad when the wind blew his favourite hat	Negative	hat	kite	boot	cheese

Examples of comprehension questions

Did the speaker say hat?

Did the speaker say kite?

Did the speaker say tomatoes?

Did the speaker say roses?

Did the speaker say drumsticks?

Did the speaker say tutu?

Did the speaker say pot?

Did the speaker say rat?

Did the speaker say socks?

Did the speaker say chocolate?

Did the speaker say worms?

Did the speaker say fishes?

Did the speaker say drain?

Did the speaker say basket?

Did the speaker say ball?

Did the speaker say chair?

Did the speaker say dentist?

Did the speaker say wheel?

Did the speaker say rabbit?

Did the speaker say tiger?

Did the speaker say dessert?

Did the speaker say bill?

Did the speaker say strawberry?

Did the speaker say fly?

Did the speaker say veterinarian?

Did the speaker say park?

Did the speaker say carousel?

Did the speaker say coaster?

Did the speaker say mole?

Did the speaker say carrot?

Did the speaker say boot?

Did the speaker say fish?

Did the speaker say worm?

Did the speaker say rabbit?

Did the speaker say hair?

Did the speaker say cheese?

Did the speaker say finger?

Did the speaker say cat?

Did the speaker say onion?

Did the speaker say spider?

Did the speaker say mailman?

Did the speaker say family?

Did the speaker say river?

Did the speaker say bear?

Did the speaker say deer?

Did the speaker say bear?

Did the speaker say cockroach?

Did the speaker say puppy?

Did the speaker say vegetables?

Did the speaker say chocolate?

Did the speaker say broccoli?

Did the speaker say chicken?

Did the speaker say tree?

Did the speaker say axe?

Did the speaker say target?

Did the speaker say dog?

Did the speaker say receipts?

Did the speaker say spanner?

Did the speaker say Lego?

Did the speaker say knife?

Did the speaker say socks?

Did the speaker say drumsticks?

Did the speaker say TV?

Did the speaker say policeman?

Did the speaker say cemetery?

Did the speaker say mall?

Did the speaker say books?

Did the speaker say snacks?

Did the speaker say vegetables?

Did the speaker say cream?

Did the speaker say cemetery?

Did the speaker say station?

Did the speaker say car?

Did the speaker say train?

Did the speaker say chocolate?

Did the speaker say fly?

Did the speaker say boot?

Did the speaker say dogs?

Did the speaker say pie?

Did the speaker say building?

Did the speaker say log?

Did the speaker say cats?

Did the speaker say wheel?

Did the speaker say basket?

Did the speaker say book?

Did the speaker say snack?

Did the speaker say book?

Did the speaker say axe?

Did the speaker say goalpost?

Did the speaker say dessert?

Did the speaker say book?

Did the speaker say hair?

Did the speaker say onion?

Did the speaker say rose?

Did the speaker say dog?

Did the speaker say knife?

Did the speaker say books?

Did the speaker say policeman?

Did the speaker say cheese?

Did the speaker say chocolate?

Did the speaker say rock?

Did the speaker say Lego?

Did the speaker say drumsticks?

Did the speaker say wheel?

Did the speaker say pie?

Did the speaker say foot?

Did the speaker say car?

Did the speaker say kite?

Did the speaker say family?

Did the speaker say bills?

Did the speaker say cat?

Did the speaker say roses?

Did the speaker say vegetables?

Did the speaker say knife?