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The Effect of Mood On Set-Switching Abilities in Younger and Older Adults

by

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Abstract

Research shows that changes in our moods can affect our performance on cognitive tasks. Most studies to date have used young adults and the interaction between mood, cognitive performance and age have rarely been examined. There are age-specific changes in executive functions and mood regulation. This study examined the effect of mood on set switching and inhibitory control by comparing performances in young and older adults after neutral, positive and negative mood inductions using forced cued based switching tasks. In a neutral mood, older adults showed reduced set switching abilities and inhibitory control compared to young adults. Consistent with the literature, young adults showed reduced switching performance in a positive mood; they made more switching errors in a visual switch task. Older participants improved their switching abilities following mood inductions in a negative or positive direction when compared to a neutral mood induction. The relationship between mood and task switching performance was significant even after controlling for working memory, reaction time and inhibitory processes. Young and older adults made different types of errors during the switching task. Proposed explanations for findings are discussed.

Keywords: executive functioning, aging, emotion, mood

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Chapter I

Introduction

Normal variations in our emotions, such as feeling sad or happy, influence the way we think and process information. For example, small changes in mood among healthy individuals have been shown to impact memory (Kliegel et al. 2005; Forgas, Goldenberg, & Unkelbach, 2009; Moore & Oaksford, 2002), attention (Rowe, Hirsh, Anderson, & Smith, 2007) and creativity (Phillips, Bull, Adams, & Fraser, 2002; Vosburg, 1998). Mood changes have also been found to impact executive functions (Mitchell & Phillips, 2007). Executive functions have been defined as a set of higher order neurocognitive processes that allow organisms to make choices and engage in purposeful, goal-directed and future oriented behaviours (Suchy, 2009). They are considered to be higher-level processes that facilitate adaption to new or complex situations when highly practiced cognitive abilities or behaviour no longer suffice (Collette, Hogge, Salmon, & Van der Linden, 2006). These higher order cognitive processes encompass lower level cognitive processes such as visual perception, auditory perception, and attention. It has been argued that the effect of mood on executive functioning may underlie mood effects on other cognitive domains such as memory, reasoning, and creativity (Ashby, Isen, & Turken, 1999; Dalgleish et al., 2007; De Dreu, Baas, & Nijstad, 2008; Oaksford, Morris, Grainger, & Williams, 1996). Any factor that affects aspects of cognition crucial for everyday functioning deserves systematic investigation (Mitchell & Phillips, 2007).

Evidence for the relationship between mood and executive functions has been shown in studies of individuals with mood disorders. For example, depressed patients demonstrated reduced working memory (Moritz et al., 2002; Harvey et al., 2004), set-shifting abilities (Austin et al., 1999), inhibitory control (Langenecker et al., 2005) and cognitive flexibility (Fossati, Amar, Raoux, Ergis, & Alliaire, 1999) compared to non-depressed individuals. Patients with bipolar disorder showed executive impairments in inhibitory control (Brooks et al., 2006; McGrath, Scheldt, Welham, & Clair, 1997), cognitive flexibility (Borkowska & Rybakowski, 2001; Frangou, Donaldson, Hadjulis, Landau, & Goldstein, 2005) and verbal fluency (Borkowska & Rybakowski, 2001; Martinez-Aran et al., 2002). Taken together, the current literature suggests that emotion plays a role cognitive functioning. Emotional processing involves the prefrontal cortex and anterior cingulate cortex, which are brain areas also important for executive functioning (Collette et al., 2005).

In the next sections, literature reviews on the definition, measurement and neuroanatomy of emotions and executive functioning are presented. Then, the theories proposed to explain the effect of mood on cognitive functioning are examined before exploring the specific research pertaining to mood effects on executive functioning. The current literature indicates a gap in knowledge regarding how age and mood interacts to impact performance on executive functioning. Changes in frontal lobe functioning have been proposed to explain age and mood related deficits in executive functioning (Brickman et al., 2007; West, 1996; 2001). Research on the changes associated with aging are also reviewed, particularly with regard to emotional and executive functioning.

Emotions and Moods

Definition and Concept of Emotions

Emotions have been defined as feelings, of shifts in the control of behaviour and thought, of involuntary and impulsive behaviours, of emergence or tenacity of beliefs, of changes in an individual’s relationship with the environment, and of physiological changes not caused by physical conditions (Frijda, 2000). The phenomenon of emotions has been heavily debated and can be loosely categorized into two perspectives. The first perspective describes emotion as discrete and natural, and proposes that each emotion is associated with a unique experience (Christie & Friedman, 2004; Ekman, Levenson, & Friesen, 1983; Izard, 1992; Oatley & Johnson-Laird, 1987). For example, Ekman (1992) proposed that there are basic, universal emotions such as happiness, sadness, anger, fear and disgust. Each emotion involves specific cognitive, behavioural and physiological components (Winkielman, Knutson, Paulus, & Trujillo, 2007). Cognitive components are changes in perception and attention related to emotion. Behavioural components refer to emotion-activated motor programs or action. Physiological components are changes in bodily and brain responses, such as hormones, cardiovascular, and subcortical changes, associated with emotion. Some researchers suggest that each emotion is the result of people's appraisal of events occurring in the environment that are significant for them (Lazarus, 1991; Roseman, Antoniou, & Jose, 1996; Scherer, 1997; Smith & Ellsworth, 1985; Weiner, 1985). For example, fear or fright is due to imminent threat unexpected in the environment when one has low coping abilities; sadness is when one does not achieve goals; and happiness is a result of success in achieving goals (Scherer, 1997).

Alternatively, the dimensional perspective argues that emotions can be organized according to underlying factors such as valence, arousal, and motivational state (Lang, Bradley, & Cuthbert, 1998; Russell & Barrett, 1999; Watson, Wiese, Vaidya, & Tellegen, 1999). The argument for a dimensional view rather than discrete emotions is supported by meta-analyses of peripheral nervous system patterns, neuroimaging data, and studies of intercorrelations among emotional experiences, which find evidence for only two factors of emotions: valence/motivation and intensity/arousal (Barrett, 2006; Mauss &

Robinson, 2009; Posner, Russell, & Peterson, 2005). Facial behaviours, reports of emotional experience, and peripheral nervous system activity show strong associations for the emotional properties of valence and intensity (Lang, Greenwald, Bradley, & Hamm, 1993). In addition, meta-analyses fail to find distinct patterns of peripheral and central nervous system responses for basic discrete emotions (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000).

According to the dimensional view, arousal or intensity refers to a hedonically undifferentiated state of general activation ranging from low to high (Watson et al., 1999). The other factor is either emotion valence or motivation, depending upon the particular theory. Valence refers to the hedonic dimension of a state, either positive and pleasurable, or negative and displeasure (Winkielman et al., 2007). This perspective views emotions as basic evaluations signaling good or bad. Motivation, on the other hand is characterized by people’s behaviour towards stimuli and there are two types of motivation: approach or avoidance. Approach motivation is characterized by a tendency to approach stimuli whereas avoidance motivation is characterized by a tendency to avoid stimuli (Davidson, 1992). Watson and colleagues (1999) labeled the avoidance system as behavioral inhibition system (BIS) and the approach system as behavioral facilitation system (BFS). In behavioral terms, the BIS is working to keep the organism out of danger and to help the organism avoid aversive stimuli. Activity in the BIS focuses maximum attention on analyzing environmental stimuli, especially novel stimuli that could potentially signal danger and motivates the organism to move cautiously until safety is indicated. In contrast, the BFS directs organisms towards situations and experiences that may yield pleasure or reward. Activity in the BFS aims to increase goal-directed behaviours (Watson et al., 1999). In general, positive emotions are linked to

BFS and negative emotions are linked to BIS. There are, however, exceptions for the relationship between mood and behavioural motivation. For example, anger is not always associated with withdrawal and has been found to be an approach emotion (Yan & Dillard, 2010).

Some researchers consider arousal as a separate variable from valence (Russell, 1980) whereas others view arousal as variations in the activation of valence (Watson et al., 1999). Using a dimensional approach, a circumplex model of affect has been proposed, which states that all emotions arise from these two fundamental neurophysiologic systems: valence – a pleasure-displeasure continuum and arousal - a low to high continuum (Russell, 1980). These two dimensions were placed in a circumplex model like a compass. The horizontal dimension was the pleasure-displeasure continuum and the vertical dimension was the arousal-sleep continuum. Four other variables were included that define the quadrants: excitement, depression, distress, and contentment (Russell, 1980). Watson and Tellegen (1985) revised the circumplex model with a circular structure by depicting the four bipolar dimensions that are spaced 45 degrees apart including: pleasantness (happy vs. sad), positive affect (excited vs. sluggish), engagement (aroused vs. still) and negative affect (distressed vs. relaxed). Watson and Tellegen emphasized the importance of negative and positive affect in addition to the basic structure Russell proposed.

In addition to the different conceptualizations of emotions, there are also a variety of different ways to measure emotions. Assessment techniques to measure emotions can be categorized into three types: 1. language-based such as self report of experience, speech patterns, and communication expressions; 2. behavioural displays such as facial expressions and behavioural patterns including flight or fight; and 3. physiological signs from hormones, heart rate, and autonomic changes such as blood pressure, skin temperature and conductance (for review see, Larsen & Prizmic-Larsen, 2006; Mauss & Robinson, 2009; see Table 1 for overview of emotion measurement). These different measurements of emotions have been criticized to be heavily influenced by societal and cultural factors (Barrett, 2006; McConatha et al., 1994; Shweder & Haidt, 2000). The available body of evidence suggests that there is no clear, objective way to measure the experience of emotion using any single measurement (Barrett, 2006; Mauss & Robinson, 2009) and that multiple methods are needed to adequately examine the multi-faceted nature of emotions (Larsen & Prizmic-Larsen, 2006).

Table 1

Overview of Response Systems, Measures, and Emotional states

Response system	Measure
Subjective experience	Self-report
Peripheral physiology	Autonomic nervous system (ANS) measures
Affect-modulated startle	Startle response magnitude
Central physiology	EEG, fMRI, PET
Behaviour	Vocal characteristics: Amplitude, pitch
	Facial behaviour: Observer ratings; EMG
Whole body behaviour	Observer ratings

Mood vs. Emotion

Although the terms ‘mood’ and ‘emotion’ have been used interchangeably in everyday discourse, the term ‘emotion’ is differentiated from ‘mood’ by various factors in scientific literature. Emotions are relatively intense, brief states whereas mood refers to low intensity, diffuse and relatively long lasting states (Winkielman et al., 2007). Moods have no salient antecedent or clear cause, and little cognitive content. Emotions have a definite cause and clear cognitive content (Forgas, 1995). Moods generally last for minutes or hours. On the other hand, emotions last for typically seconds or a fraction of a second (Mitchell & Phillips, 2007).

Neuroanatomy of Emotions

The question of where emotion or mood processing occurs in the brain has been a topic of debate for decades. The work of Papez has been particularly influential in this regard. Papez (1937) theorized that a complex emotion processing circuit exists within the hypothalamus, anterior thalamic nucleus, hippocampus, and cingulate cortex. The hypothalamus was thought to be the structure that assigns incoming stimuli with emotional significance whereas the cingulate cortex was thought to be involved in the experience of emotion. This circuit was later revised and relabeled as the limbic system, a system that includes the amygdala, hypothalamus, anterior thalamic nucleus, hippocampus, and insular cortex (MacLean, 1952).

Researchers now generally agree that several of the limbic system structures play an important role in emotional processing. The amygdala has been found to detect and recognize emotionally salient stimuli (Davis & Whalen, 2001; Morris, Frith, Perrett, & Rowland, 1996). The amygdala is located in the medial temporal lobe, anterior to the hippocampus. Typically, processing information from the environment begins at the sensory organs and then transferred to the sensory specific nuclei of the thalamus. Subsequently, information is either relayed to the sensory cortex before transferring to the amygdala, or the thalamus passes information directly to the amygdala (LeDoux, 1995).

The amygdala incorporates three distinct groups of cells: lateral, basal, and central nuclei. In general, the lateral nucleus receives information from the thalamus, hippocampus, or cortex and then transmits information to the basal and accessory basal nuclei where it is integrated with information coming from different areas of the brain (Davis & Whalen, 2001; LeDoux, 1995). Information is then transmitted to the central nucleus where it is output to the prefrontal cortex, hippocampus, striatum, central nucleus, anterior cingulate, and the lateral bed nucleus of the stria terminalis. The amygdala and its connections are involved in emotional arousal, processing positive and negative emotions, and memory consolidation of emotional events (Baxter & Murray, 2002; Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; LeBar & Cabeza, 2006; Liberzon, Phan, Decker, & Taylor, 2003; Siebert, Markowitsch, & Bartel, 2003).

In addition to the amygdala, the reticular formation (RF) has been suggested to regulate arousal levels of the central nervous system through its connections with the limbic system and thalamus (Heilman, 1997). The RF is located within the brain stem with its cell bodies located in the midbrain and pons. The ascending neural projections from the RF are composed largely of neurons producing the excitatory neurotransmitter glutamate. Neuroimaging research found that thalamic and frontomedial activity is associated with arousal changes (Anders, Lotze, Erb, Grodd & Birbaumer, 2004). Heller (1993) suggested that the parietotemporal region of the right hemisphere modulates emotion arousal whereas the frontal regions modulate the valence dimensions of emotion. Activation in the temporal and parietal areas has been associated with emotional arousal (Anders et al., 2004; Foster & Harrison, 2002) and increased activation in the frontal cortex occurs when individuals are induced in a positive or negative mood (Baker, Frith & Dolan, 1997; Lane et al., 1997; Steele & Lawrie, 2004). Additionally, activity in the medial and lateral prefrontal cortex increased when people consciously altered their appraisals of aversive stimuli and ventral lateral prefrontal cortex activation was inversely correlated with the activation of the amygdala (Ochsner, Bunge, Gross, & Gabrieli, 2002; Phan et al., 2005). In a review of neuroimaging studies, Quirk and Beer (2006) found that activation of the ventromedial prefrontal cortex and inhibition of the amygdala are involved in regulating emotions, especially suppressing negative emotions.

Furthermore, research shows that positive and negative emotions rely on independent neural mechanisms. Happiness and joy activate the basal ganglia (Phan, Wager, Taylor, & Liberzon, 2002) and are marked by increased dopamine levels in the brain, especially in the anterior cingulate cortex (Ashby et al., 1999) and ventral striatum (Burgdorf & Panksepp, 2006; Drevets et al., 2001). Support for the association of dopamine in positive mood comes from studies showing amphetamine injections, which increase dopamine in the ventral striatum, were correlated with self-reported positive arousal (Drevets et al., 2001; Volkow, Wang, Fowler, Logan, Gatley et al., 1999). On the other hand, negative moods, such as sadness and fear, have been associated with activity in the subcallosal cingulate cortex and amygdala (Mayberg et al., 1999; Phan et al., 2002) and low levels of serotonin in the prefrontal cortex (Arango, Underwood, & Mann, 1997; Beevers, Scott, McGeary, & McGeary, 2009; Bhagwagar, Whale, & Cowen, 2002). This suggests that positive and negative emotions are relatively orthogonal dimensions, rather than opposites on a single continuum, because positive and negative emotions are processed by distinct cortical regions.

There are two main theories for the lateralization of emotions in the brain. Based on the right hemisphere model, the right hemisphere is specialized for general emotional processing regardless of valence (Borod, 1992; Borod et al., 1998; Hagemann, Hewig, Naumann, Seifert, & Bartussek, 2005). In this model, the right hemisphere is for automatic emotional processing whereas the left hemisphere is for emotional control and modulation (Qinqxia & Dejun, 2004). General emotional processing has been suggested to involve the posterior regions of the right hemisphere (Gur, Skolnick, & Gur, 1994; Heller, 1993; Heller, Nitschke, & Lindsay, 1997). On the other hand, the valence model states that positive or approach emotions are associated with relatively greater left hemisphere activity and negative or withdrawal emotions are associated with relatively greater right hemisphere activity (Coan & Allen, 2004; Davidson, 1992; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Specifically, Davidson (1992) proposed that the left frontal area is involved in a system facilitating positive approach behaviour to appetitive stimuli whereas the right frontal area is involved in a system facilitating negative withdrawal behaviour from aversive stimuli.

Executive Functioning

Definition and Measurement

The scientific literature contains multiple definitions of executive functioning and there is no universally accepted operational definition. Broadly speaking, the term *executive functioning* is a set of higher order neurocognitive processes that allow organisms to make choices and engage in purposeful, goal-directed and future oriented behaviour (Suchy, 2009). Many higher order cognitive abilities are subsumed to be executive functioning including planning, sustained attention, working memory, problem solving, sequencing, response selection, behavioural control, inhibition of pre-potent responses, initiation of behaviour, planning of action, hypothesis generation, cognitive flexibility, judgment and decision making, and feedback management (Collette et al., 2006; Mitchell & Phillips, 2007; Suchy, 2009). Generally, executive function has been conceptualized as a top-down processor that modulates or controls lower level cognitive processes.

Although the umbrella term of executive functioning implies there is an underlying factor common to all domains, correlations between different aspects of executive functioning are often low or insignificant (Friedman et al., 2006; Lehto, 1996; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Salthouse, Atkinson, & Berish, 2003). The multifaceted nature of executive functions makes it difficult to measure adequately. Many different clinical measures have been developed to examine the various subdomains of executive functions. There is no single measure that adequately accounts for all aspects of executive functioning and there is no clear consensus on what tasks should be used to measure executive function (Strauss, Sherman, & Spreen, 2006). Additionally, there is an issue of impurity in measurement because executive functions must operate on other cognitive functions, such that all executive tasks must involve nonexecutive cognitive processes. Furthermore, many tasks used to measure executive function use several different executive function abilities. Many popular executive function tasks have been validated only to the loose criterion of being affected by frontal lobe damage and the precise nature of executive processes implicated in the performance of these tasks has not been adequately specified (Miyake et al., 2000).

Theories Conceptualizing Executive Functions

One of the earliest conceptualizations of executive functions is from Luria (1973), who proposed that the brain is organized into three functional units. The first unit is for regulating arousal and wakefulness, the second unit is for receiving, processing, and storing information from the external world, and the third unit is for programming, controlling, and verifying activity. This latter unit was the ‘executive’ system in the brain that allows individuals to engage in higher-level thinking and problem solving. Luria posited that this executive system was likely located in the prefrontal lobe based on clinical observations of brain-damaged patients.

Norman and Shallice (1986) also suggested an executive system for higher-level thinking. Generally, they believed in two different levels of cognitive processing depending on task complexity. When a task is simple, well-learned or rehearsed, the brain operates at a lower-level of automatic responding by choosing the appropriate response based on activation of a network of schemas, which they called the contention scheduling mechanism. On the other hand, when a task is novel or complex, an additional system called the supervisory system is used to select response action. This system is used when there is no available contention scheduling or existing scheduling must be overruled. This supervisory system regulates lower level schemata.

Similarly, in his theory of working memory, Baddeley (1986) suggested there is a central executive for regulating the distribution of resources for two lower level systems. In this theory, there are two slave systems for processing and temporarily storing information. The phonological loop is for processing auditory information whereas the visuospatial sketchpad is for processing visual information. Later, Baddeley (1996) expanded the role of the central executive to include selective attention to relevant stimuli while inhibiting irrelevant stimuli, switching between retrieval plans, dividing attention between two different tasks occurring simultaneously, and temporary activation long-term memory for attaining information.

Logan (1985) proposed that our cognitive system has an executive function to control and coordinate separate cognitive processes such as encoding, transforming, and recognizing information. Logan suggested there are four major executive functions when performing a task: choosing among different strategies for performing a task; constructing the strategy to enable performance of the task; executing and maintaining the strategy to perform the task which requires making decisions on what to do next as each step is completed; and lastly disengaging strategies. This last step occurs when the task is completed or the goal is no longer relevant or when the individual needs to correct errors; therefore it involves monitoring changes in task environment.

Rabbitt (1997) examined the literature on executive functions in normal and clinical populations and reported seven different distinctions executive functions have from other non-executive cognitive functions. Firstly, executive functions deal with novel tasks that require us to formulate goals, plan, and choose between alternative sequences of behaviour to reach goals, and compare these plans in respect to the relative probabilities of success at attaining the chosen goal, to initiate the plan selected and carry it through. Secondly, executive functions require retrieval from long-term memory; it involves the efficiency of organized recall of material from memory. Thirdly, executive functions initiate new sequences of behaviour and interrupt other ongoing sequences of responses in order to do so. This involves suppressing or inhibiting automatic and habitual responses with task appropriate responses and switching attention to new information if necessary. Executive functions also prevent responses that are inappropriate in context; this stems from research showing that patients with frontal lobe damage show poor social judgment. Fifthly, executive functions are responsible for strategic allocation and synchronization of responses; this is especially seen in dual task performance in which people carry out simultaneous performance of two tasks and must switch between the two tasks. In addition, executive functions monitor performance to detect and correct errors, and to change plans when one is unlikely to succeed with the current strategy. Lastly, Rabbitt pointed out that executive functions enable sustained attention over long periods of time.

Kimberg and Farah (1993) created a model based on the performance of patients with frontal damage on four different tasks: a motor sequencing test, the Wisconsin Card Sorting Test, the Stroop Test and a memory for context or source memory task. These authors hypothesized that there are information-specific working memory systems for each task, which are specific production systems developed to cope with different situations. This model was created to explain the lack of association between patients' performance deficits and lesions. Changes in working memory systems will result in disruption to performance of some tasks while leaving others unaffected. Kimberg, D'Esposito and Farrah (1997) updated their model to explain that actions are selected based on four different sources of activation: (a) priming effects in which actions taken recently are more active; (b) baseline strength in which actions that are used more often are more active; (c) inherent level of activation of a working memory element and spreading activation from other associated representations; (d) the constant level of random noise that contributes to each possible response. Therefore in this model when selecting among competing responses, the brain calculates the sum of the sources of activation contributing to each potential response and chooses the response with the highest level of activation

Similar to Kimberg and Farah (1993), Stuss and colleagues (Stuss, 2007; Stuss & Alexander, 2000) proposed a model of executive functioning based on research in patients with focal frontal lesions. Stuss proposed there are four different functions of frontal lobes: executive cognitive functions that are involved in the control and direction (including planning, switching, and monitoring) of lower-level, more automatic functions; behavioural self regulation functions for situations where habit or environmental cues are not sufficient to determine the most adaptive response; activation regulating functions which initiate behaviour at a level appropriate to the situation and to attain the individual's goals; and metacognitive processes implicated in personality, social cognition, and self-awareness. In a more recent model, Stuss (2011) suggested two main processes associated with executive cognitive functions: monitoring of ongoing performance and task setting that uses the logic of if-then. This theory was based on neurological findings that these different functions were anatomically related to different brain areas of the prefrontal cortex.

Barkley (1997) defined executive function as major classes of behaviour towards oneself used in self regulation. Self regulation is a response that functions to change the probability of future responses to an event and therefore changes the likelihood of a later consequence associated with that event. Barkley proposed that behavioural inhibition underlies many executive functions. Barkley (1997; 2001) defined behavioural inhibition as three interrelated process: Inhibition of the previously appropriate response to an event, stopping of an ongoing response, and delay in responding and goal directed behaviour generated from disruption of competing events and responses. The ability to use behavioural inhibition is important in being able to perform four different executive functions: working memory, self-regulation of affect and arousal, internalization of speech and reconstitution. The four executive functions that influence the motor system for goal directed behaviour include inhibiting task irrelevant response, generating novel complex responses for goal directed responses, maintaining sensitivity to response feedback, and assuring task re-engagement following disruption. Barkley used this theory to describe the evolutionary importance and development of executive functioning as well as to conceptualize the response inhibition difficulties in individuals with Attention Deficit Hyperactive Disorder (ADHD).

While the conceptualization of executive functions in relation to other cognition abilities is still being debated, researchers have attempted to group executive functions into meaningful categories. For example, Baddeley (1996) proposed four different executive functions: capacity to allocate resources during simultaneous execution of two tasks, capacity to switch retrieval strategies, capacity to selectively attend to one stimulus and inhibit disrupting effects of others, and capacity to hold and manipulate information stored in long term memory. Shimamura (2000) also suggested four executive control processes underlying the self-regulation of behaviour: selecting, or focusing attention on particular subsets of the mental or physical environment; maintaining, or keeping goals or other information active in working memory over time; updating, or manipulating the contents of working memory; and rerouting or switching from one task or mental set to another. Barkley (2001) suggested six different executive components: volition; planning of purposeful, intentional goal directed action; inhibition and resistance to distraction, problem solving including strategy development, selection and monitoring; shifting actions in order to meet task demands; persistence towards attaining goals; and self awareness.

Some researchers have attempted to resolve the problem of measurement and different conceptualizations of executive functions by employing factor analysis. This statistical method reduces the effects of task impurity and heterogeneity from different executive function measures by pooling shared variance from executive function tests. Based on factor analytical studies of common executive tasks. Miyake and colleagues

(2000) examined the neural correlates of latent domains of executive functioning using an undergraduate population and found three latent executive abilities: shifting, updating and inhibition. A confirmatory factor analysis indicated that shifting, updating, and inhibition were clearly distinguishable from each other but also share some underlying commonality because correlations between them were moderately high. Miyake and colleagues also used a series of structural equation modeling analyses to examine how updating, shifting, and inhibition contributed to performance on a number of executive tasks commonly used in neuropsychological studies and found that the three variables or combination of them contributed significantly to most neuropsychological measures.

There is supporting research for Miyake's three latent variables of executive functioning. Lehto, Juujarvi, Kooistra, and Pulkkinen (2003) used exploratory and confirmatory analyses on the performance of various executive functioning measures among children aged 8 to 13 years old, and found three interrelated factors similar to Miyake's. Friedman, Miyake, Robinson, and Hewitt (2011) also found the same three-factor model in a large twin study with 950 children and adolescent participants. Using a large population of participants aged 20 to 81, Fisk and Sharp (2004) found a factor structure broadly consistent with Miyake and colleagues. Vaughan and Giovanello (2010) found a similar three-factor model among older adults using confirmatory factor analysis. Adrover-Roig, Sesé, Barceló, and Palmer (2012) also examined executive functioning among older adults using latent variable analysis and found factor structures broadly consistent with Miyake et al.'s three-factor model, however, an additional factor labeled 'efficiency of access to long-term memory', and a mediator factor ('speed of processing') were also found. A three-factor solution of working memory, shifting and access to long-term memory best described executive functioning among healthy older adults. Huizinga, Dolan and van der Molen (2006) also found shifting and updating factors using confirmatory factor analysis on participants from four different age groups (7-, 11-, 15-, and 21-year olds). In a more recent model, Miyake and Friedman (2012) updated the unity/diversity model of executive functioning to include a common executive functioning ability, specific updating ability, and a specific shifting ability. The inhibition specific ability was taken out of the new model because research showed that there was no unique variance left for the inhibition-specific factor once the common executive function factor was accounted (Friedman et al., 2011).

Neuroanatomy of Executive Functions

Originally, executive functions were synonymous with the brain's frontal lobes because research demonstrated that patients with frontal lesions showed executive function deficits (Strauss et al., 2006; Suchy, 2009). Current research demonstrates that executive function is not exclusively associated with the frontal lobe but involves a neural network of multiple brain areas. Abundant research shows that the neural network of executive functions includes the prefrontal area of the brain and anterior cingulate (Barbas, 2000; Collette et al., 2006; Gilbert, Gonen-Yaacovi, Benoit, Volle, & Burgess, 2010; Heyder, Suchan, & Daum, 2004; Koechlin & Summerfield, 2007; Sarazin et al., 1998). The prefrontal cortex can be divided into three subdivisions: the dorsolateral area, which is associated with working memory, the superomedial area including the anterior cingulate gyrus, which is associated with sustained attention, response selection and motivation, and the ventral area, which is associated with inhibition (Suchy, 2009). The prefrontal cortex controls processes throughout the brain to achieve goals; activity in the prefrontal cortex can affect sensory systems, motor systems, and midbrain systems to control behaviour (Miller & Cohen, 2001). Stuss (2011) proposed a network of the frontal lobes associated with different cognitive processing: the superior medial area is involved in initiating and sustaining a response (also called energization), the right lateral area is for monitoring performance, the left lateral area is for task setting, the ventromedial prefrontal cortex is for behavioural and emotional self-regulation, and the rostral area is for metacognition and integration of all the other different capacities. In addition to the prefrontal area, the parietal lobe has also been shown in neuroimaging studies to be involved in different executive functioning tasks (Collette et al., 2006) as well as subcortical structures such as the basal ganglia, thalamus, and cerebellum (Collette et al., 2006; Heyder et al., 2004; Rueda, Posner, & Rothbart, 2005; Stuss, 2011).

Theories of Mood Effects on Cognition

Many researchers have attempted to explain the effect of mood on cognition. Some theories focus on the processing demands of emotions, also known as capacity limitation theories. Other theories focus on the evolutionary significance emotions have for our cognitive functioning and hypothesize different processing styles associated with positive and negative mood, referred to collectively as processing style theories. Lastly, the mood as facilitator theory proposes that positive mood will facilitate cognitive processes. The following section will describe these theories.

Capacity Limitation Theories

In the capacity limitation theories (Ellis & Ashbrook, 1988), changes in mood lead to the activation of associative networks of emotion-related thoughts, which reduce the resources available for cognitive task processing. Emotions activate emotion nodes, which then prime the associated network to decrease threshold for emotionally congruent cognitive nodes. Each distinct emotion has a node or unit in memory that collects together many aspects including expressive behaviours, autonomic patterns, evoking appraisals, verbal labels, and events in one's life where that emotion is aroused (Bower, 1981). Activation of an emotion node spreads activation throughout memory structures connected to it and reduces subsequent excitation required for activation at those event nodes. For example, Wenze, Gunthert, and Forand (2007) found a significant relationship between presently occurring negative mood and negative thoughts. Emotions are also associated with emotion-congruent memories and information processing (Bower, 1981; Innes-Ker & Niedenthal, 2002; Niedenthal, Halberstadt, & Setterlund, 1997); for example sad mood produces sad memories. Seibert and Ellis (1991) found that happy and sad mood participants showed greater irrelevant thoughts than control participants and the proportion of irrelevant thought was negatively related to memory recall performance.

These emotion-related thoughts reduce the amount of processing capacity available for task-related processes because resources are being used to process one's mood state or other mood congruent task irrelevant information. For example, Schmeichel (2007) found that participants who had performed a working memory task (evaluating math equations while remembering target words presented on screen) were less successful at inhibiting their emotional expressions while watching a negative emotion film afterwards compared to participants who had performed a memory maintenance task. Moreover, participants who were asked to exaggerate facial expressions of their emotions while watching happy and disgusting films showed reduced performance on a working memory span compared to participants who were not asked to exaggerate their emotions. This suggests that performing an executive functioning task undermined later efforts at engaging in emotion control and vice versa, engaging in emotional control reduced performance on an executive task. Given that negative moods are undesirable, people are motivated to reduce or eliminate them by regulating their negative mood (Joormann & Siemer, 2004). Ochsner and colleagues (2004) measured prefrontal activity using functional imaging when participants engaged in cognitive reappraisal to up- and down-regulate negative emotion generated from viewing negative images. Regulation of emotion activated regions of the lateral prefrontal cortex implicated in working memory, the dorsal anterior cingulate implicated in the on-line monitoring of performance, and the dorsal medial prefrontal cortex implicated in self-monitoring and self-evaluation. Regulation of emotions also modulated amygdala activation. This demonstrates that effective cognitive reappraisal after negative mood involves activation of prefrontal systems related to executive functioning and systems that appraise the properties of stimuli.

In summary, capacity limitation theories suggest that negative and positive mood would negatively impact cognitive functioning: the greater intensity of emotion arousal, the greater performance deficits on cognitive tasks. In support for emotional arousal impacting cognitive processing, Pham (2007) reviewed the literature on emotion and cognition and concluded that highly intense negative emotional states interfere with reasoning ability because under high activation of negative emotions (e.g. fear), behavioural responses are based on quick assessment of diagnostic features of the situation rather than careful consideration (Baron, Inman, Kao, & Logan, 1992). The effects of highly intense positive emotional states are less well understood; however, they may have less influence on reasoning processes because it requires less behavioural adjustment than negative emotions (Pham, 2007). Generally, positive emotions signify safe situations that require little action whereas negative emotions indicate problematic situations that require action (Schwarz & Bless, 1991).

Processing Style Theories

The processing style theories examine mood from an evolutionary point of view. These theories view mood functioning as information to alert people to safety or threat (Schwarz & Bless, 1991). The threat of danger or problematic situations creates a negative mood, prompting people to engage in systematic information processing for action to remedy their current situation whereas the signal of safety during positive moods prompts people to relax and therefore, they are more likely to explore novel pathways and take risks. Similarly, Fiedler (1988) described positive mood as producing a "loosening style" of being creative and intuitive, and negative mood as producing a "tightening style” of being systematic and conservative. Research suggests that positive mood led to global processing with broader range of thought action repertoires and greater attention scope (Bolte, Goschke, & Kuhl, 2003; Fredrickson, 2001; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). The greater associations primed in positive mood may distract people from careful systematic information processing (Mackie & Worth, 1989). Also, positive mood may lead to increased activation of task irrelevant information in working memory, leading to greater flexibility and originality at the cost of reduced inhibition for irrelevant information or increased distractibility (Dreisbach & Goschke, 2004; Goeleven, De Raedt, & Koster, 2007; Rowe et al., 2007). Alternatively, negative mood has been found to be associated with more localized, focused processing as a result of the activation of narrow available action repertoires (Bolte et al., 2003; Fredrickson & Branigan, 2005). Negative mood is also associated with concrete, systematic processing rather than heuristic processing (Forgas, 2007), which would serve well on executive function tasks that require focused and analytical thought.

Another way of differentiating the processing styles of positive and negative mood is assimilation versus accommodation (Fiedler, 2001). Positive mood supports assimilation: a top-down adaptive process which imposes one's own internal structures onto the environment; thus one relies on internal schemas and routines to respond to situations. In contrast, negative mood supports accommodation: a bottom-up process by which internal structures are changed because of external constraints; therefore this promotes assessing the environment as accurately and carefully as possible. Negative mood indicates a problematic situation and that relying on usual routine may not be adaptive; therefore, it is important to pay attention to the specifics of a situation. Bless and colleagues (1996) suggested that when people are in a happy mood, they are more likely to rely on their general knowledge structures because these structures are likely to serve them well because the situation is benign. On the other hand, people in a sad mood are in a problematic situation and focusing on specific information is more adaptive than relying on usual routine and general knowledge structures.

In support for the predictions of processing style theories, positive mood has been associated with using superficial, heuristic categorization such as stereotypes to judge people (Bodenhausen, Kramer, & Süsser, 1994; Park and Banaji, 2000; Stroessner & Mackie, 1992), categorizing objects more broadly (Isen & Daubman, 1984; Isen, Niedenthal, & Cantor, 1992), lower likelihood to use rule-based decision strategies to maximize outcome in a gambling task (De Vries, Holland, Corneille, Rondeel, & Witteman, 2012), committing the fundamental attribution error (Forgas, 1998), relying on the ease of access to relevant information and general knowledge structures for judgment (Bless et al. 1996; Ruder & Bless, 2003), producing more abstract, less concrete arguments (Forgas, 2007), and generating a greater number and more creative answers in response generation tasks (Abele-Brehm, 1992; Hirt, Devers, & McCrea, 2008; Hirt, Melton, McDonald, & Harackiewicz, 1996; Phillips, Bull et al., 2002). Positive mood is also associated with using distracting information implicitly (Biss, Hasher, & Thomas, 2010), greater implicit memory for irrelevant information (Biss & Hasher, 2011) and greater processing of spatially adjacent distractors (Rowe et al., 2007); consistent with the suggestion that positive mood is associated with increased distractibility. On the other hand, negative mood is associated with greater substantial and systematic information processing in persuasion (Bless, Bohner, Schwarz, & Strack, 1990; Ruder & Bless, 2003; Ruys & Stapel, 2008; Sinclair, Mark, & Clore, 1994), decreasing reliance on general, easily accessible knowledge structures (Bless et al., 1996; Converse, Lin, Keysar, & Epley, 2008), reducing susceptibility to halo effects (Sinclair, 1988), decreasing the likelihood of committing the fundamental attribution error (Forgas, 1998), and producing attitude change with effective arguments (Forgas, 2007).

In summary, these processing style theories hypothesize that positive and negative mood would have different effects on cognition. Positive mood would improve performance on tasks that require using heuristics, creativity and flexibility. Alternatively, negative mood would improve performance on tasks that require focused attention and ignoring distractors, and systematic and detailed analysis. Furthermore, Fielder (2001) suggests negative mood calls for accommodative processing focused on concrete and external information, and thus is best for dealing with novel, difficult or problematic situations. Positive mood promotes assimilative processing in which individuals rely on abstract knowledge structures and heuristics, and is therefore appropriate for creative use of abstract, established knowledge structures. Therefore, given that executive measures often use novel, complex tasks, the processing style associated with negative mood would improve performance on such tasks whereas positive mood would hinder task performance.

Mood as Facilitator Theory

In contrast to the idea that an assimilation style is associated with positive mood, Ashby, Isen, and Turken (1999) suggested that mild positive mood acts as a facilitator for cognition. Specifically, positive mood is proposed to activate positive memories and thoughts to help promote flexibility, efficient thinking, and problem solving. Neurologically, Ashby and colleagues (1999) suggested that positive mood increases dopamine levels in the prefrontal cortex and anterior cingulate. Increases in dopamine levels are associated with updating of working memory, which facilitates cognitive flexibility and learning (Cohen, Braver, & Brown, 2002). However, the effect of positive mood on cognition depends on motivation. Positive mood will facilitate cognition if motivation for the task is high, as based on the affect maintenance theory (Isen & Geva, 1987). That is, people in a positive mood are motivated to spend cognitive effort in completing a task if the task has direct bearing on their well-being or the task itself is perceived as intrinsically enjoyable because they generally want to maintain their positive mood. Positive mood is often associated with reduced performance and increased heuristic processing in research because the tasks measured in a laboratory are inconsequential to participants. On the other hand, people in a positive mood during everyday situations will quit using heuristics if it is not working and use systematic processing if they are motivated to perform well on the task (Lyubomirsky, King, & Diener, 2005). Therefore, the mood as a facilitator for cognition theory predicts that positive mood would improve task performance on important or enjoyable tasks whereas it would impair performance on dull and unpleasant tasks. There are no predictions regarding cognitive performance for negative moods.

In summary, the capacity limitation theories state that positive and negative mood would be associated with reduced cognitive performance and the greater the mood arousal, the greater the decline in performance. The processing style theories suggest that positive and negative mood would have different effects on cognition. Positive mood would improve performance on tasks that require using heuristics or abstract general knowledge structures, creative thinking and flexibility. On the other hand, negative mood would improve performance on tasks that require focused attention on concrete, external information, and systematic and detailed analysis, and for novel, difficult problems. Mood as a facilitator for cognition theory predicts that positive mood generally improves cognitive performance if individuals find the task important or enjoyable, but decreases performance on tasks that are relatively unimportant or boring.

Factors that Influence the Effects of Mood on Cognition

Various factors have been found to affect the relationship between mood and cognitive task performance. A factor important in determining task performance is the degree of motivation and effort. Emotions affect motivation by increasing or decreasing an individual's willingness to engage in an effortful task (Martin, Ward, Achee, & Wyer, 1993); motivational principles state that happy people preserve good mood by avoiding cognitive effort and sad people increase cognitive effort to improve mood (Isen & Geva, 1987). Therefore, people in a positive mood are not motivated to expend cognitive effort unless it is called for by other goals (Côtè, 2005). As such, individuals in a positive mood have been found to use greater scrutiny in activity choice than individuals in a negative mood (Wegener & Petty, 1994). Individuals in a happy mood preferred tasks that were pleasant and creative (Hirt et al., 2008).

The impact of mood on cognition is reduced or eliminated when there is explicit motivation for task performance (Ottati, Terkildsen, & Hubbard, 1997). That is, motivation can reduce or eliminate mood effects if, for example, a strong external motivator such as a high reward, is provided to participants (Forgas, 1995). Sansone and Harackiewciz (1996) argued that motivation derives not only from the goal that the individual wants to achieve, but also from the individual's phenomenal experience while working towards a goal, meaning that the individual's mood during a task constitutes a part of task motivation. Similarly, the degree of effort required for the task can also affect mood such that effortful cognitive tasks reduce mood effects or return induced mood to baseline regardless of valence whereas easy tasks do not (Erber & Tesser, 1992; Van Dillen, & Koole, 2007).

Task framing also influences mood effects on cognitive performance. Friedman, Forster and Denzler (2007) found that participants in a positive mood performed better on tasks framed as fun and silly and participants in a negative mood performed better on tasks framed as serious and important. Martin, and colleagues (1993) found that participants whose attention was focused on their enjoyment persisted on the task longer and showed better performance when in a happy mood whereas participants whose attention focused on the adequacy of their performance persisted on the task longer and showed better performance when in a sad mood. A study performed by Hirt et al. (1996) found that participants in a happy mood performed better and spent longer time on tasks when asked to stop when they were no longer interested in the task but they spent less time on tasks when asked to stop when they thought it was a good time to stop.

Research demonstrates that interest generally increases task performance (Frost & Mahoney, 1978). Task interest plays a role in the effect of mood on cognition. Abele-

Brehm (1992) found that positive mood was associated with greater fluency regardless of task interest whereas negative mood was associated with greater fluency only when there was a high instrumental interest compared to neutral mood. In addition, research has found that task interest levels partially mediated the effect of mood on task performance (Hirt et al., 1996) in which initial task interest resulted in more response generation from participants.

Given that all these factors impact mood and cognition, Forgas (1995; 2002) proposed the affect infusion model. According to this model, there are various factors in deciding which strategy individuals use to make social judgments such as the target's familiarity, complexity, and personal relevance, and the judge's specific motivation and cognitive capacity. Although this theory is for social judgments, the model can be applied in a similar manner for other aspects of cognitive functioning. For example, motivated processing for preexisting goals uses predetermined, selective and directed information search patterns and integration strategies. This is generally used when there are strong and specific motivation pressures for the outcome to be achieved. In this case, the motivation consequences of moods are more subtle and indirect, such as mood repair or mood maintenance. On the other hand, heuristic processing refers to judgments based on quick processing with little reference to the environment or judgment inferred from prevailing affect state. This type of processing is most likely to occur when the situation is simple or highly typical and does not demand high accuracy or detailed consideration, and the individual has limited cognitive capacity. In contrast, substantive processing is a generative strategy to compute outcome by selecting and interpreting novel information about the environment and to relate information to preexisting knowledge. This occurs when the individual has cognitive capacity and is motivated to be accurate because of implicit or explicit situational demands, and the situation is complex or atypical. This model highlights the fact that processing consequences of mood can be indirect and are context dependent.

Mood Effects on Executive Functioning

Given the strong evidence and research support for Miyake and colleagues' (2000) three latent variables of executive functioning abilities, the literature on the effect of mood on executive functions will be reviewed based on the areas of updating, inhibition and shifting.

Updating

Updating requires actively manipulating relevant information in working memory; it involves monitoring and coding information relevant to the task at hand and then appropriately updating the items held in working memory by replacing old and no longer relevant information with new more relevant information (Miyake et al., 2000). Updating has been found to be associated with activation in the dorsolateral prefrontal cortex, inferior frontal cortex, and anterior cingulate (Collette et al., 2006). Updating is often investigated through paradigms in which one must select among a set of representations that are simultaneously active and choose the one representation that is most relevant to the task goal (Banich et al., 2009). A task often used to measure updating is the N-back test, in which items (usually numbers or letters) are presented sequentially and participants have to decide whether a given item is the same as the one presented *n* items previously.

Studies have found that induction of an approach state (positive mood) using films showed improved verbal N-back test performance and declined spatial or visual N-back test performance compared to neutral mood whereas induction of a withdrawal state (negative mood) showed improved spatial or visual N-back test performance and declined verbal N-back test performance compared to a neutral mood (Gray, 2001; Gray, Braver, & Raichle, 2002). Similarly, participants induced into a negative mood, disgust through olfactory stimulation, showed reduced verbal N-back test performance compared to a neutral mood (Koch et al., 2007). The participants in this study also rated their arousal levels as higher when they were in a negative mood than a neutral mood. Therefore, the performance decline may have also been associated with higher arousal.

On the other hand, some studies have not found the interaction between mood valence and task modality. Kliegel and colleagues (2005) found no difference in performance on a verbal N-back test between negative and neutral moods induced by films and music. But the authors only examined error rates and did not measure reaction times, which may be more sensitive to detect differences. Another study examined negative mood on updating by applying physical shocks or threat of shocks (Shackman et al., 2006) during performance on verbal and spatial N-back tests. Participants in the negative mood group had reduced accuracy on the spatial but not on the verbal N-back test compared to participants who received no shocks or threat of shocks. Physiological measures of anxiety such as EMG activity in brow muscles and acoustic startle reflex mediated the reduction in spatial task performance. A crucial difference in this study compared to other studies is that mood induced by the threat of shock or receiving shock is much higher in arousal than other studies using films or music. Given that the impact of anxiety and arousal on performance follows an inverted U pattern (Yerkes & Dodson, 1908), the arousal level in previous studies may have enhanced spatial updating but the higher arousal from the shocks negatively impacted spatial updating performance in this study.

The available research findings do not support capacity limitation theories because there are tasks that are improved by positive and negative mood compared to neutral mood. The processing style theories would suggest that the heuristic processing of positive mood would impair updating capacity, but studies found that positive mood improved updating on certain tasks. In addition, the systematic processing of negative mood based on processing style theories would improve updating performance, but this was not always the case. Evidence for mood as a facilitator theory for updating is unclear because studies did not measure task enjoyment or task importance. However, positive mood improving performance on one task and reducing performance on another when the tasks are similar in nature does not suggest enjoyment or importance could account for the results. Therefore, none of the current psychological theories account for research on updating and mood.

Updating performance differences as a function of mood and task modality may be explained by research in neuroimaging. As previously mentioned, greater left prefrontal activity is related to positive mood and greater right prefrontal activity is related to negative mood (Davidson, 1992). Complex working memory tasks for verbal information generally depend more on left prefrontal cortex and spatial information depend more on right prefrontal cortex (Smith & Jonides, 1999). There is evidence suggesting that regionally specific, lateralized activation of brain regions relevant to a task is associated with better performance (Davidson, Chapman, Chapman, & Henriques, 1990; Gur et al., 2000; Gur, Ragland, Resnick, & Skolnick, 1994; Papousek & Schulter, 2004; Wendt & Risberg, 1994), meaning that activation of the right hemisphere as a result of negative mood produced better performance on tasks that also use the right hemisphere. The greater the magnitude of task appropriate hemisphere activation relative to the other hemisphere, the greater the task performance. For example, individuals induced into a negative mood performed better on tasks involving visual targets presented in the left visual field than in the right visual field (Simon-Thomas, Role & Knight, 2005; Van Strien & Morpurgo 1992). Studies found that individuals who were induced into a positive or approach mood showed a better performance in verbal fluency than individuals induced in a negative mood whereas those induced in a negative or withdrawal mood had better figural fluency than those in a positive mood (Bartolic, Basso, Schefft, Glauser, & Titanic-Schefft, 1999; Papousek, Schulter, & Lang, 2009). In line with this reasoning, the effect of mood on updating appears to depend on the nature of the task; positive mood was associated with reduced performance on visually oriented tasks but improved performance on verbally oriented tasks and the negative mood showed the opposite pattern. This relationship between updating and mood occurs when there is a moderate level of mood arousal because high mood arousal reduces working memory performance regardless of the task.

Inhibition

Inhibition can be described as preventing the production of predominant but inadequate responses or suppressing information when it becomes irrelevant (Friedman & Miyake, 2004). It involves the ability to resist or resolve interference from distracting information in the external environment that is irrelevant to the task at hand, and the ability to inhibit memory intrusions from information that was previously relevant to the task but has since become irrelevant (Miyake et al., 2000). Inhibition has been associated with multiple areas of the brain including the cingulate, prefrontal, parietal, and temporal areas (Collette et al., 2006). A widely used task measuring inhibition is the Stroop task.

In this task, people are asked to name the colour of ink in which a coloured word is printed and to suppress the tendency to read the colour word (e.g. say red for the word 'blue' printed in red ink). Longer colour-ink reading times indicate difficulty inhibiting the habitual dominant response of reading. Other measures of inhibition include the Go/no-go task and Flanker task. In the Go/no-go task, participants are asked to respond to all stimuli except for one, which is shown infrequently; again participants must inhibit automatic responding. In the Flanker task, the target items that participants must respond to are surrounded by distracting symbols that must be ignored, some which are compatible with the target and some are incompatible with the target. Reaction time is typically slower for targets flanked by incompatible compared to compatible stimuli, which is referred to as 'flanker interference.'

Several studies have examined the effect of positive mood on inhibition. Stafford, Ng, Moore, and Bard (2010) compared Stroop performance between positive and neutral mood induced by music and found no difference in interference times or error rates between groups. Likewise, Martin and Kerns (2011) found no difference in performance on the Stroop task or Flanker task between positive and neutral mood groups induced by film. A study conducted by Phillips and colleagues (2002) using memory recall to induce mood found that participants induced to have a positive mood took longer on the Stroop task than when they were in a neutral mood; but this trend only approached significance. These studies suggest that positive mood does not affect inhibition.

Other studies have examined performance on inhibitory measures following negative mood induction. Chepenik, Cornew, and Farah (2007) compared negative and neutral mood induced by music and imagery in the same participants and found no difference in their performance on the Stroop task or the Go/no-go task. Finkelmeyer et al. (2010) induced negative and neutral mood using odours and found that participants who rated the odours as high in arousal and negative in valence showed better performance on the Stroop. Given that negative valence was also rated high in arousal compared to the neutral mood, it may be that high arousal was responsible for creating the performance boost. Another confound in this study is that participants only rated the valence and arousal of odours and not their moods. Melcher, Obst, Mann, Paulus and Gruber (2012) examined inhibition between negative and neutral mood using Stroop and Flanker tasks. Moods were induced using sad and neutral faces shown before task trials. Participants were better at inhibiting their responses on both tasks after shown sad than neutral faces, suggesting that negative mood may be associated with improved inhibition. In contrast, individuals induced in a negative mood using autobiographical sad scripts made more errors in the incongruent trials than congruent trial on the Stroop task than baseline neutral measurement, indicating greater difficulty inhibition dominant responding (Nixon, Liddle, Nixon, & Liotti, 2013). These studies show contradictory and inconclusive results on negative mood and inhibition.

Studies that examined both positive and negative moods have also found conflicting results. For example, Kuhl and Kazen (1999) found that showing positive emotional words before a Stroop trial reduced the interference effect in the Stroop task. There was no difference in Stroop interference performance between participants in the negative and neutral group. On the other hand, Braun-LaTour, Puccinelli, and Mast (2007) induced mood using film clips and found that individuals who watched a negative film clip showed a slower reaction time when performing the Stroop. There was no difference in Stroop performance between those who watched positive and neutral film clips. A major limitation of these two studies is that the authors did not check whether there were actual changes in participants' mood after the mood induction. Chu and Abeare (2011) found no difference in Stroop interference times or anti-saccade accuracy levels between neutral, positive and negative-induced mood groups. They found a trend indicating that the negative mood group had the highest reaction time difference suggesting that the negative group had greater difficulty inhibiting their eye movements in comparison to the neutral and positive mood groups as revealed by the greater response time. Brand, Verspui, and Oving (1997) also compared self-reported changes in negative, positive, and neutral mood on the Stroop interference task. Although there was no difference between groups in overall reaction time, the negative mood group showed greater reaction times when making errors than the positive mood group. Smallwood, Fitzgerald, Miles, and Phillips (2009) induced mood using film clips and then assessed several performance factors on a variant of the Go/no-go task, in which participants must inhibit a response to an infrequent target, called the sustained attention to response task. Results indicated that negative mood was associated with greater errors and less behaviour adjustment following lapses, meaning greater attention lapses than positive mood. Interestingly, there was no performance difference between positive and neutral mood. Consistent with this finding, another study using sounds to induce mood during performance on the Go/no-go task found that the response times were longer for participants in a negative mood compared to positive or neutral moods (Yu, Yuan, & Luo, 2009).

Similarly, participants induced in a high arousal, negative mood such as anxiety showed lower accuracy rates when performing the Flanker task compared to no mood induction (Larson, Gray, Clayson, Jones, & Kirwan, 2013). Mood was induced using music and memory for previous mood-congruent events. Low arousal, negative mood (e.g., sad) and high and low arousal positive mood (e.g., calm and happy) did not show any performance difference from no mood induction. Rowe and colleagues (2007) examined performance on the Flanker task between individuals induced in a negative, positive, and neutral mood with music. Participants in a positive mood showed greater flanker interference compared to when they were induced in a neutral or sad mood. There was no performance difference between sad and neutral mood. In addition to inhibition, the Flanker task requires selective attention to attend to central target and ignore distractors. Broadened attention scope can reduce performance on this task; therefore, Rowe and colleagues (2007) investigated the role of attention by manipulating the processing difficulty through perceptual crowding and comparing near versus far flankers. The spacing of flankers affected performance in positive mood; far incompatible flankers demonstrated greater interference relative to compatible flankers. This suggested that increased attention scope may account for the performance difference on the flanker task for individuals in a positive mood.

Overall, the current literature showed conflicting results on the effect of mood on inhibition. However, examining only studies in which mood manipulation checks were conducted and there were no apparent confounding factors, negative mood was often associated with decreased inhibitory control whereas positive mood did not affect inhibitory control. The one study that found positive mood associated with increased reaction time on an inhibitory task (Rowe et al., 2007) may have reflected greater attention scope rather than inhibitory control. The collective results of these studies do not provide evidence for the mood as a facilitator theory because positive mood was not associated with greater inhibitory control and instead showed similar performance to those in a neutral mood. It is possible that the positive mood induced in studies was not strong enough to show performance differences, as it is difficult to induce positive mood at a moderate arousal level. The lack of measurement for task interest or motivation in these studies does not allow us to adequately evaluate the mood as facilitator theory. The processing style theories would suggest that the distractibility and heuristic processing style of positive mood leads to reduced inhibitory control whereas the systematic processing style of negative mood improves inhibition, but this contradicts the results of most studies. There is some support for capacity limitation theories as negative mood was associated with reduced cognitive performance; however, this was not consistently found. In addition, the majority of studies found no difference in performance between positive and neutral moods, contradictory to theory predictions. In summary, none of the current theories fit the results of studies examining mood effect on inhibition.

Shifting

Shifting is defined as efficient reactions to environmental stimuli that require rapid and frequent shifts between different aspects of a stimulus or between different cognitive operations (Collette et al., 2006). This is also often referred to in the literature as switching, and therefore will be used interchangeably with switching in this paper. Shifting process involves the disengagement of an irrelevant task set and the subsequent active engagement of a relevant task set (Miyake et al., 2000). Shifting has shown to be related to activation in the prefrontal, parietal, and subcortical areas (Collette et al., 2006; Dove, Pollmann, Schubert, Wiggins, & von Cramon, 2000; Yeung, Nystrom, Aronson, & Cohen, 2006). In shifting tasks, participants perform two or more different tasks within a series of trials, and performance on trials that involve switching between tasks is compared to that for trials without a switch. Participants showed longer response latencies when they had to perform a switched task than a repeated task; this is known as the switch cost (Collette et al., 2006). Cues given beforehand (before the trial begins) about which task to complete and practice switching between specific tasks were found to reduce but not eliminate switch costs (Allport, Styles, & Hsieh, 1994; Meiran, 1996). Switch costs that are present even when individuals are given time to prepare for the switch is known as residual switch cost (Cepeda, Kramer, & Gonzalaez de Sather, 2001). The evidence for residual switch cost suggests that the increased reaction time when individuals switch between tasks is robust. Switch costs occur with forced switching, in which a cue is provided asking participants to switch (Arbuthnott & Frank, 2000), and voluntary switching, in which participants are told to switch between two tasks on their own while performing each task equally often and in a random sequence (Arrington & Logan, 2004; 2005). Switch cost has been distinguished between global or general effect and specific or local effect (Hahn, Andersen, & Kramer, 2004; Madden et al., 2010). The global switch cost represents the additional demands of switching while completing a dual task compared to a single task, as measured by the difference in reaction time for repeated trials in dual-task blocks (i.e., AABA from single-task blocks i.e., AAAA). The specific switch cost represents the switch in task trials across individual trials and is measured by the difference in reaction time for switch trials i.e., AABA compared to repeated trials within a dual-task block i.e., AABA. Both types of switch costs have been found in the literature (Arrington & Logan, 2004).

Phillips, Bull and colleagues (2002) examined the effects of positive mood induced by reading emotional stories in two different switching tasks: alternating verbal fluency and alternating Stroop. On the alternating fluency task, individuals were asked to switch between category and lexical fluency. The neutral group performed better on the alternating verbal fluency than the positive group. The neutral group was also quicker at the alternating Stroop task in which participants had to switch between naming the colour of the ink and reading the coloured word. Phillips, Bull and colleagues (2002) suggested that alternating verbal fluency and Stroop tasks used forced switching rather than the spontaneous switching that is frequently measured in creative tasks. In forced switching, there is a need for effortful suppression of a previously active task set and then activation of a previously suppressed task set. Alternatively, Braun-Latour and colleagues (2007) found that participants in a negative mood were slower at switching between randomly congruent and incongruent stimuli in the altering Stroop task whereas participants in a positive mood performed similar to participants in the neutral mood. In this study, mood was induced using film clips but there was no measure of mood after induction to ensure actual mood changes. Stafford and colleagues (2010) also compared Stroop alternating performance between positive and neutral mood induced by music and found no difference in reaction time or error rates between groups. Unlike Phillips and colleagues' study, they examined performance on two other tasks. Although the tasks were counterbalanced for order, mood changes may have dissipated due to the length of time between mood induction and task performance.

Zhou and colleagues (2011) examined the effect of negative mood on a switching task in which participants determined whether a digit was odd/even or high/low. Faces were used as cues for which task to perform; male faces indicated that participants should do one task whereas female faces indicated participants should do the other task. These faces were also manipulated to induce mood (fearful vs. neutral faces). Zhou found that switch cost was larger in trials containing the fearful face cues than the neutral face cues. Again, the lack of mood measurement and possible arousal difference between fearful and neutral faces make it uncertain whether the effects are specific to negative mood.

Chu and Abeare (2011) examined mood effects on shifting sets using the Stroop alternating and written fluency tasks in young adults. The Stroop alternating task required participants to switch between naming colour ink and reading colour words. Alternation cost compared the reaction time on the alternating task to the two control tasks of colour naming and reading words; therefore greater alternation costs indicate greater difficulty switching. Compared to the practice trials, participants in the neutral and negative mood groups showed a lower switch cost after the mood induction; thus they became better at switching. Participants in the positive mood group were slower on the Stroop alternating trial after the mood induction. There were no group differences on the written fluency-alternating task. The results suggest that compared to neutral mood, negative mood may improve switching in a rigidly structured task whereas positive mood may decline switching on such a task. When there is greater flexibility allowed in a task such as on the written fluency-alternating task, no mood effects were demonstrated.

Dreisbach and Goschke (2004) found that positive mood induction using pictures was associated with faster performance when participants had to switch to responding to stimuli of a new colour while distractors appeared in a formerly relevant colour (perseveration condition). Alternatively, positive mood was associated with slower switching performance when participants had to respond to a previously task irrelevant stimuli and ignore novel distracters (learned irrelevance condition). This increased switch cost during positive mood may reflect greater interference from novel distractors due to broadening of the attention scope. But the positive pictures chosen were higher in arousal than neutral pictures, so the authors conducted a second experiment using negative valence pictures with similar arousal ratings as the positive pictures. They found that individuals who saw the negative pictures performed similarly to the neutral group

(Dreisbach & Goschke, 2004). In this study, mood again was not checked following the manipulation.

In summary, the literature suggests that the effect on mood appears to depend on the type of set-switching task. Positive mood as compared to neutral mood was associated with greater switch costs when the task involves forced switching or switching to previously task irrelevant stimuli while ignoring novel distractors. On the other hand, positive mood was associated with improved switching abilities when the task required responding to new stimuli and ignoring previously relevant distractors. Studies examining the role of negative mood in set-switching found conflicting results (Braun-Latour et al., 2007; Dreisbach & Goschke, 2004); however, most of the studies did not measure mood after induction so it is unclear whether the negative mood induction worked. Chu and Abeare's (2011) study which reported negative mood following mood induction found that negative mood was associated with lower switch cost in Stroop alternating task compared to neutral mood but no difference in switching on an alternating written fluency task.

The current literature related to positive mood and set-switching are most consistent with the processing style theories (Bolte et al., 2003; Fiedler, 2001; Fredrickson & Branigan, 2005; Schwarz & Bless, 1991). The increased flexibility of positive mood would improve the performance on tasks that require responding to new stimuli but the increased distractibility would impede performance on tasks that show distractors in a new colour and on tasks that require a forced switching response. This body of research does not support the capacity limitation theory because contrary to predictions made by this theory, positive mood was associated with better performance on certain switching tasks when compared to neutral mood (Dreisbach & Goschke, 2004).

The mood as facilitator theory would predict that positive mood would be associated with greater switching abilities than neutral mood, but studies did not consistently find this. It can be argued that poor performance of positive mood on some switching tasks may have been a reflection of poor interest or motivation from participants, however, the lack of control for these variables make it difficult for us to fully discount this theory. There is neurological evidence supporting these findings. Phasic dopamine increases in the prefrontal cortex and anterior cingulate as a result of positive mood serve as a gating signal that updates working memory and facilitates switch of cognitive set (Braver, Barch, & Cohen, 1999, Miller & Cohen, 2001; O'Reilly, 2006). Cohen and colleagues (2002) suggests that phasic bursts of dopamine convey important reward-related information; these neurons show rapid, stimulus-specific response to salient stimuli in the environment. Phasic bursts of dopamine activity signal which information should be selected and stored in the prefrontal cortex and thereby protected from intervening distractors, until a behavioural response occurs. Motor activation from responding suppresses the dopamine system to return to baseline levels until the next working memory update. Dreisbach et al. (2005) investigated the role of dopamine activity in executive functioning using spontaneous eye blink rate. Spontaneous eye blink is a functional marker of central dopaminergic functioning, it is increased in primates with dopamine agonists and reduced in patients with Parkinson's disease. Therefore, eye blinking is directly correlated with reduced dopamine activity in subcortical areas. Dreisbach et al. (2005) found that those with high eye blinking demonstrated impaired performance in the learned irrelevance condition and better performance in the perseveration condition, similar to performance of individuals induced in a positive mood. Muller et al. (2007) also found that high eye blink rate predicted better switching cost in preservation condition and reduced switching cost in the learned relevance condition. These findings suggest that dopamine activity associated with positive mood enhances cognitive flexibility but also increases distractibility.

Interpretation of Mood Effects on Executive Function

A review of the current literature suggests that the relationship between mood and cognition is not a simple one. None of the present theoretical models adequately explain all the results. The capacity limitation theories suggest that mood changes reduce cognitive processing capacity as a result of resources being used up for emotion related thoughts (Ellis & Ashbrook, 1988). This hypothesis was not supported across any examined domains of executive function. Positive and negative moods were rarely associated with significantly reduced performance as compared to neutral mood. On the contrary, evidence suggests that positive and negative moods improve performance on certain cognitive tasks. The mood as a facilitator theory suggests that positive mood is associated with improved cognitive performance when there are adequate levels of motivation and task enjoyment (Ashby, Isen & Turken, 1999). Although positive mood was not consistently associated with increased cognitive performance, none of the studies measured motivation or task enjoyment levels. Therefore, the current studies cannot provide evidence to fully discount the mood as a facilitator theory.

Studies on set-switching abilities seem to provide some evidence for the processing style model. These models suggest that positive mood is associated with heuristic processing and reliance on general knowledge whereas negative mood is associated with systematic processing and detailed analysis of the external environment (Fiedler, 1988, 2001; Schwarz & Bless, 1991). Studies demonstrate that positive mood is associated with slower reaction time on forced switching tasks as hypothesized by the processing style theories. On the other hand, predictions based on the processing style of negative mood were not supported because there were conflicting results for effects of negative mood on all aspects of executive functioning; some studies found facilitation and other studies found suppression. Furthermore, there was greater evidence for reduced inhibitory control when individuals are induced in a negative mood, which would be contrary to predictions of the processing style models.

Research on mood and working memory suggests that hemispheric processing differences may play a factor in the relationship between mood and executive functions. Past research has found greater left prefrontal activation for positive mood and greater right prefrontal activation for negative mood, and that regionally specific, lateralized activation of brain regions relevant to a task is associated with better performance (Gur et al., 2000; Papousek & Schulter, 2004; Wendt & Risberg, 1994). There is evidence for a double dissociation for mood valence and different measures of working memory (Gray, 2001; Gray, Braver, & Raichle, 2002), positive mood associated with left hemisphere activity was related to increased performance on verbal working memory whereas negative mood associated with right hemisphere activity showed increased performance on visual working memory tasks. This suggests that the nature of the task may play a factor in the relationship between mood and executive function. The lack of studies comparing visual and verbal tasks in inhibition and shifting makes it difficult to ascertain whether this finding extends to all aspects of executive functioning. Future studies should examine if there are cognitive performance differences across stimuli type for measures of all executive functions following positive and negative mood induction.

Older Adults

Aging Related Changes in Executive Function and Emotions

The majority of the studies that examined mood effects on executive functioning used young adults as participants. However, the relationship between mood and executive functioning may differ between older and younger adults because older adults show changes in executive functioning abilities compared to young adults. Research indicates that various executive functioning abilities, such as inhibition, (Andrés & van der Linden, 2000; Klein, Ponds, Houx, & Jolles, 1997; Samanez-Larkin, Robertson, Mikels, Carstensen, & Gotlib, 2009; Treitz, Heyder, & Daum, 2007; Troyer, Leach, & Strauss, 2006; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000), planning (Andrés & Van der Linden, 2000; Kliegel, McDaniel, & Einstein, 2000), set-switching (Cepeda et al., 2001; Keys & White, 2000; Kray & Lindenberger, 2000; Meiran, Gotler, & Perlman, 2001; Robbins et al., 1998), and working memory (Bopp & Verhaeghen, 2005; Salthouse & Skovronek, 1992) have been shown to decline with age. For example, Treitz and colleagues (2007) examined cognitive functioning among four consecutive age groups (20–30 years, 31–45 years, 46–60 years, and 61–75 years) in a large population study in which participants were matched on intelligence and mood. They found that aging was associated with deficits in inhibition and divided attention and these changes in executive functions started occurring between 60 and 70 years of age (Mathersul et al., 2008; Treitz et al., 2007).

Researchers have attempted to determine the underlining reason for age-related cognitive decline. While some researchers suggested that slower processing speed accounted for age-associated cognitive decline (Adrover-Roig et al., 2012; Baune, Suslow, Engelien, Arolt, & Berger, 2006; Salthouse, 1995; Uttl & Graf, 1997;

Verhaeghen & De Meersman, 1998;), other studies indicated that processing speed does not completely account for reduced cognitive abilities in older adults (Andres & Van der Linden, 2000; Bucur et al., 2008; Cepeda et al., 2001; Keys & White, 2000; Robbins et al., 1998; Salthouse & Ferrer-Caja, 2003; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). Another factor that may explain the age-related decline in executive function is processing style. In order to conserve their limited resources, it has been suggested that older persons rely more on heuristic processes (Yates & Patalano, 1999). Older adults were more likely than young adults to adopt heuristic strategies rather than systematic-processing strategies unless given environmental support (Klaczynski & Robinson, 2000; Mutter & Poliske, 1994; Wang & Chen, 2004); this heuristic strategy may undermine performance on executive functioning tasks that often require systematic processing. Working memory has also been suggested to explain age-related cognitive decline in older adults (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Park et al., 1996; Park et al., 2002). Goffaux, Phillips, Sinai, and Pushkar (2008) examined task-switching components between younger and older adults categorized by high or low working memory capabilities. Younger and older participants with high working memory capacities had similar reaction times and performed better than older participants with low working memory capacities, suggesting that working memory capacity abilities may help older adults with their set-switching abilities. Kramer, Hahn and Gopher (1999) also found that older adults showed reduced switching cost with practice under low memory load (where they were given cues indicating when to switch) but not under high memory load (where they had to remember to switch after a certain number of trials). This suggests that working memory may be a factor that influences shifting performance in older adults.

Atrophy of neurons in the frontal network has also been proposed as the reason for cognitive decline (Dempster, 1992; West, 1996), including executive functioning, associated with old age. Although many brain areas show neurological decline with normal aging (Brickman et al., 2007; Hedden & Gabrieli, 2004), neuroimaging studies indicated that the volume and activation of frontal lobes decreased with age more so than other brain areas (Azari, Rapoport, Salerno, & Grady, 1992; Grieve, Clark, Williams, Peduto, & Gordon, 2005; Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; Tisserand & Jolles, 2003; Van Petten et al., 2004). Studies found that volume loss in the prefrontal cortex and white matter hyperintensities were associated with reduced executive function in older adults (Gunning-Dixon & Raz, 2003; Raz et al., 1998). Furthermore, cognitive changes observed in normal aging have been linked to the decline in function of the dopamine system projection to the prefrontal cortex (Bäckman, Nyberg, Lindenberger, Li, & Farde, 2006; Braver & Barch, 2002).

One area of executive functioning that does not show a decline with aging is emotional regulation. Early studies found that the intensity and frequency of self reported emotion declined with age (Diener, Sandvik, & Larsen, 1985; Lawton, Kleban, Rajagopal, & Dean 1992). This age decline did not appear to be associated with reduced reactivity to emotion provoking stimuli because multiple studies found no age differences in self reported reactivity to mood induction procedures (Labouvie-Vief, Lumley, Jain, & Heinze, 2003; Levenson, Carstensen, Friesen, & Ekman, 1991; Reminger, Kaszniak, & Dalby, 2000; Tsai, Levenson, & Carstensen, 2000). Although older adults did not report differences in emotional reactivity, it is unclear whether they respond physiologically different from younger adults. Some studies found that older adults show less physiological arousal to emotion provoking stimuli (Labouvie-Vief et al., 2003; Levenson et al., 1991; Tsai, Levenson, & Carstensen, 2001) while other studies found no difference in emotional physiology between older and younger adults (Kunzmann & Grühn, 2005; Kunzmann, Kupperbusch, & Levenson, 2005; Reminger et al., 2000).

Further examination of emotional experiences in older adults suggested reduced negative emotional experiences (Birditt & Fingerman, 2003; Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Gross et al., 1997). Carstensen and colleagues (2000) asked participants to record their emotions when they were paged at random times throughout the day for a week. Participants indicated which emotions they were experiencing and how intensely they felt them. The study found that positive emotions were maintained in both frequency and intensity across adulthood whereas negative emotions declined in frequency. Older people also rated negative pictures as less emotionally arousing than younger adults whereas they experienced comparable emotional arousal to positive pictures (Mather et al., 2004). Similarly, Gross and colleagues (1997) using an ethnically- and culturally-diverse sample found that age was associated with decreased negative emotional experiences such as anger, sadness, and fear and increased experiences of happiness. They also found that age was associated with increased emotional control, particularly internal control. Gross and colleagues suggested that as we age, we have increasingly effective emotional control and therefore, selectively enhance positive emotion and dampen negative emotions. Evidence for this selective dampening of negative emotions was found in emotional memory studies where older adults were less likely to recall and recognize negative images compared to positive or neutral images than younger adults (Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2003), and engaged in more elaborative processing when retrieving positive memories than when retrieving negative memories (Mather & Knight, 2005). Although many studies find a decrease in negative emotional experience among older adults, not all studies do (Kliegel, Jäger, & Phillips, 2007; Pearman, Andreoletti, & Isaacowitz, 2010; Reminger et al., 2000).

Direct support for the theory that older adults show greater emotional control is that older adults themselves reported having greater emotional control compared to younger and middle aged participants (Lawton et al., 1992; McConatha, Leone, & Armstrong, 1997; Phillips, Henry, Hosie, & Milne, 2008). Older adults were more effective at mood repair after a negative mood induction than younger adults (Kliegel et al., 2007; Pearman et al., 2010). They were also more effective than young adults at solving everyday problems, in particular for interpersonal problems (Blanchard-Fields, Mienaltowski, & Seay, 2007) and showed higher scores than young adults on three of four branches of an emotional intelligence test (Kafetsios, 2004). A recent study by Scheibe and Blanchard-Fields (2009) examined people's regulation of emotions while they performed a working memory task. Disgust was induced using a film clip and different instructions were given regarding emotion regulation. When instructed to down-regulate disgust feelings, young adults' working memory performance was reduced after the mood induction whereas working memory performance was unaffected in older adults. These results suggest that older adults are better able to regulate their emotions so that it does not interfere with cognitive processing. Different theories have been proposed to explain the increased emotional control associated with aging (for review of theories, see Scheibe & Carstensen, 2010), including age is associated with greater motivation for emotional control because of life goals from perception of time (Carstensen, Issacowitz, & Charles, 1999), diminishing cognitive capacities that makes it difficult to process negative emotion and therefore older adults minimize negative feelings (Labouvie-Vief, 2003), and differential use of emotional regulation strategies including proactive instrumental strategies due to life experiences which makes older adults more competent in emotional control (Blanchard-Fields, 2007).

Mood Effects on Executive Functioning in Older Adults

The present literature suggests that older adults have reduced executive functioning in many areas but show improved emotional regulation along with decreased negative emotion processing (Carstensen et al., 2000; Gross et al., 1997; Kliegel et al., 2007; Phillips et al., 2008). Additionally, neuroimaging studies demonstrated that deterioration of the frontal lobe is associated with aging (Grieve et al., 2005; Raz et al., 1998; Resnick et al., 2003). Theories on the effects of mood on cognition have been built on research using young participants, therefore, it is uncertain how the various theories will account for age-related changes in older adults. One possibility is the effects of frontal lobe deterioration in aging may be exacerbated by the presence of positive or negative mood states when performing cognitive tasks. Older adults may perform even worse on measures of executive functioning when induced into positive or negative mood because of increased emotional processing load compared to being in a neutral mood or compared to young adults induced in similar moods. On the other hand, older adults were found to be better able to regulate their emotions, especially negative ones, and therefore, may show less mood effects on executive functioning. Thus, they may react similarly to a neutral mood when induced in a positive or negative mood, especially when in a negative mood because this has been found to be reduced in older adults.

Only a couple of studies have examined the effect of mood on executive functioning in older adults. Baune and colleagues (2006) investigated the effect of depressed mood on the performance of neuropsychological tests using a population-based cross sectional study for participants aged 65 to 83 years. Depressed mood was measured using a self-report scale called the Center for Epidemiologic Studies Depression Scale (Radloff, 1977). Neuropsychological measures used in the study assessed episodic memory, word fluency, inhibition, processing speed and motor function. Although multivariate linear regression analyses revealed a significant effect of depressive symptoms on processing speed and motor functioning, depressed mood was not associated with performance on the Stroop interference task. This study examined depressive symptoms, which includes many other symptoms in addition to sad mood. Therefore, it is uncertain whether these findings will translate to normal, negative mood changes. Phillips, Smith and Gilhooly (2002) induced positive, negative and neutral moods using films and music in older and younger adults before measuring their performance on a planning task (the Tower of London; TOL). They found that older adults in a positive or negative mood state performed poorly compared to young adults on the Tower of London task. Even though young adults induced into a happy mood also showed lowered performance on the TOL, the performance reduction was greater among older participants induced in a happy mood. In contrast, there was no difference in performance between young adults who were in a negative mood and a neutral mood, however, older adults in a negative mood were more likely to make excess moves than older adults in a neutral mood. Despite that the negative mood manipulation in this study produced a significant reduction in mood ratings, most of the participants still rated their mood as more positive than negative. In addition, older adults generally rated their mood as more positive than young adults and showed an increase in reported mood between post mood induction and after task completion (irrespective of mood induction condition) whereas young adults did not. Phillips, Smith and colleagues (2002) suggested that older adults were engaging in some form of mood improvement while they performed the task and proposed that lower working memory capacity in older adults made it harder for them to deal with an extra load imposed by positive or negative mood induction. Mood induction may operate something like a dual-task load, occupying processing capacity. A limitation of Phillips, Smith et al. (2002) study is that the performance difference between older and younger adults may be partially related to increased general positive mood because older adults rated their mood as more positive across all time points in the study and positive mood has been found to reduce planning abilities (Oaksford et al., 1996).

In summary, there has only been one study (Phillips, Smith et al., 2002) that examined executive functioning in older adults following mood inductions. Findings from this study suggested that older adults showed lowered performance on a planning task after mood induction, regardless of valence, compared to neutral mood. Additionally, older adults showed worse performance than younger adults following positive and negative mood induction. These results are consistent with the capacity limitation theories that hypothesize that positive and negative moods is associated with reduced performance compared to neutral moods.

Chapter II

Study

This present study aims to fill the gap in the literature by examining the effect of mood on shifting abilities in young and older adults. It is important to examine our shifting abilities because of their applicability to everyday function. We switch from doing different tasks in our daily lives. Previous studies often examined positive and negative moods without a neutral group or compared a neutral group with either a positive or negative group. It is important to compare performance between positive, negative, and neutral mood; otherwise it is difficult to ascertain whether changes are due to specifically mood valence or arousal levels or both. This present study compares induced positive and negative moods to a neutral mood. This research study examines the role mood changes have on young and older adults' shifting performance using a forced cued based switching task.

The literature on shifting processes has distinguished between global and specific switch costs. Global switch cost, which is the comparison between reaction times from repeated trials in dual task blocks and repeated trials in single task blocks, is confounded by different working memory demands because there is a greater working memory demand in dual task blocks compared to single task blocks (Kray & Lindenberger, 2000). In dual task blocks, it is necessary to maintain task instructions for different tasks in working memory. Given that older adults show declined working memory, this study examined specific or local shift costs –the increase in reaction times from switch trials compared to repeated trials within dual task blocks to reduce the confound of working memory demands affecting performance in older adults. In this study, switching performance was measured by switching cost and number of errors made. Switching cost was measured by subtracting reaction time (RT) on non-switch trials (trials in which there was no switching involved, e.g., AAA) in switching conditions from RT on switch trials in switch conditions (trials in which participants asked to switch from one task to another, e.g., ABA). Participant errors were distinguished between switch errors, which are failures to switch between tasks (e.g. indicating number of syllables when task was to determine shape) and decision errors, which are selecting the wrong response within a correct task set (e.g. deciding an animal as inanimate). Difficulty switching between two tasks is indicated by greater switch costs and/or more errors made.

Research suggests that switching between different operations on a set of stimuli involves retrieval of a task set on each trial, disengaging from irrelevant task set, and actively engaging relevant task set (Miyake et al., 2000). Shifting has been suggested to involve overcoming proactive interference or negative priming due to having previously performed a different operation on the same type of stimuli (Wylie & Allport, 2000). Thus, the ability to inhibit plays a role in task shifting because it reduces interference from irrelevant dimensions of the task. In this study, interference from irrelevant dimensions was examined by using repeated stimuli for a different task operation (e.g. see "cow" and asked to do Task A and then see "cow" again but asked to do Task B). Participants switched from stimuli repeated just recently (two trials ago) and from stimuli repeated a while ago (trials that occurred more than four trials ago). Inhibition control was measured by subtracting reaction time for repeated stimuli that occurred two trials ago from reaction time for repeated stimuli that occurred more than four trials ago. Greater residual inhibition is associated with the more recently abandoned set compared to the less recently abandoned set (Mayr, 2001; Mayr & Kliegel, 2003). Reduced inhibitory control was defined as greater reaction times on recently repeated trials than previously repeated trials in the switching conditions. The number of errors made when responding to the repeated stimuli was also counted; greater number of errors also indicated reduced inhibitory control.

Research Questions and Hypotheses

Young Adults. The current literature on mood effects in shifting performance among young adults provides some evidence for the processing style theories. Based on the processing style theories, we expect young adults to show decreased shifting abilities when in a positive mood compared to a neutral mood when performing a forced set-switching task due to increased distraction and use of heuristics. In contrast, young adults would show increased shifting abilities when in a negative mood compared to a neutral mood because of greater focused attention and systematic analysis. Given that inhibitory control plays a role in set shifting, we would expect that young adults would show reduced inhibitory control in a positive mood whereas improved inhibitory control in a negative mood compared to a neutral mood during the set shifting task.

Older Adults. Given the lack of studies examining mood effects on executive functioning in older adults, it is uncertain whether they will show similar performances to young adults. A past study found that older adults performed more poorly on a planning task when induced in negative and positive moods than neutral mood (Phillips, Smith, et al., 2002); this finding is consistent with the capacity limitation theories. Frontal regions of the brain deteriorate with aging, and frontal areas have been found to be involved in processing emotions and set-switching abilities. Therefore, older adults may show reduced switching performance when induced in positive or negative mood because of an increased emotional processing load. Research indicates that performing an executive functioning task undermined later efforts at engaging in emotion control, and engaging in emotional control reduced performance on an executive task among young adults (Scheibe & Blanchard-Fields, 2009). This trend of emotional control undermining executive functions may be magnified in older adults who show brain deterioration in areas used to perform these tasks (Schmeichel, 2007). In addition, the effects of positive mood might be magnified for older adults who tend to engage in more heuristic processing than young adults. According to this line of reasoning, older adults would show greater shift costs and make more errors when they are in a negative and positive mood compared to when they are in a neutral mood. Older adults would also have greater shift costs, reduced inhibitory control and make more errors than young adults following positive and negative moods inductions.

Alternatively, older adults were found to be better at regulating their emotions, especially negative emotions. Therefore, their increased emotional regulation skill may result in less mood effects on executive functioning due to mood repair. Scheibe and Blanchard-Fields (2009) showed that young adults' working memory performance was reduced after the mood induction when instructed to down regulate negative feelings whereas older adults' memory performance showed no performance difference between negative and neutral mood when asked to down regulate feelings, suggesting that older adults are better able to regulate their emotions so that it does not interfere with cognitive processing. Thus, older adults when induced in a positive or negative mood may show no performance difference compared to a neutral mood, especially in a negative mood because older adults are more likely to repair negative moods. That is, older adults will show no difference in their switch cost, inhibitory control or the number of errors made between negative, positive and neutral mood induction states.

Older vs. Young Adults. Past research has found a decline in set-switching abilities for older compared to young adults (Kray & Lindenberger, 2000; Meiran, Gotler, & Perlman, 2001). Older adults demonstrated reduced inhibitory control by taking longer to disengage from a previously performed task than young adults (Cepeda et al., 2001). As such, we would expect older adults to show decreased set-switching abilities (as measured by greater switching cost and/or more switching errors) and reduced inhibitory control (as measured by greater inhibition reaction time difference and/or more errors) compared with young adults under a neutral mood.

Theories. This study also tests two proposed theories. Previous studies have not adequately tested the mood as a facilitator theory. This study examines hypotheses based on this theory by measuring participants' interest and motivation levels. The mood as a facilitator theory suggests that positive mood would be associated with better switching abilities compared to neutral mood if task interest level and motivation are high. However, if task interest and motivation are low, participants in a positive mood would show reduced switching abilities compared to neutral mood.

Research from working memory tasks suggests that performance on cognitive tasks may differ by task modality. Specifically, positive mood appeared to facilitate performance on verbal tasks but reduced performance on visual tasks. Negative mood showed the opposite performance pattern. There is evidence that regionally specific, lateralized activation of brain regions relevant to a task is associated with better performance (Gur et al., 1994, 2000; Wendt & Risberg, 1994). This study investigates if this pattern holds true for tasks measuring shifting abilities by using two comparable switching tasks, one that requires verbal processing and the other that requires visual perceptual processing. According to this lateralization pattern, the greater activation of the right hemisphere as a result of a negative mood induction should produce better performance on tasks that also use the right hemisphere (visual switching task) compared to a neutral mood. On the other hand, greater activation of the left hemisphere from a positive mood induction should produce better performance on tasks that also use the left hemisphere (verbal switching task) compared to a neutral mood.

Methodology

Participants

Sixty young adults aged 18 to 25 were recruited from the University of Toronto, Scarborough campus through the psychology participant pool. The study was posted online and students from the psychology pool signed up for the different appointment timeslots available. Fifty-five older adults aged 65 and older were recruited from a research pool at Baycrest, a geriatric hospital in Toronto, Ontario, and from the community through advertisements posted at local community centers. The Baycrest research pool provided the phone numbers of the older adults or older adults saw the research advertisement and contacted the author. The author then contacted the older adults by phone to explain the study, to briefly screen for any history of chronic psychiatric illness, neurological disorder, learning disability and substance abuse and to set up the appointment.

Participants who self reported a history of chronic psychiatric illness, neurological disorders (e.g. stroke, seizures, head injuries), learning disability and substance abuse were excluded (*n* = 8). Potential alcohol abuse was briefly screened using the CAGE questionnaire (Mayfield, McLeod, & Hall, 1974); participants who answered yes to two of the four questions were excluded (*n* = 1). Symptoms of anxiety and depression were screened using the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) and individuals endorsing severe levels of depression or anxiety were excluded from participating in the study (*n* = 8). General cognitive functioning was assessed using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). The MoCA provides a maximum score of 30, individuals who scored 20 and below were excluded because it is an indication of cognitive difficulties or difficulty with the English language

(Waldron-Perrine & Axelrod, 2012) (*n* = 1). The Hopkins Verbal Learning Test-Revised (HVLT-R; Benedict, Schretlen, Groninger, & Brandt, 1998) was also administered to screen out any older adults with possible mild cognitive impairment; participants who scored below 2.5 SD from appropriate age-based mean for the total recall score were excluded (*n* = 15). English fluency and estimated vocabulary were measured using the North American Adult Reading Test (NAART; Blair & Spreen, 1989). The score on the NAART can be used to predict expressive vocabulary using the equation of Estimated Vocabulary Scaled Score = 4.112 + 0.167(NAART Score) + 0.115(years of education). Individuals who scored an estimated vocabulary scaled score of 7 and below were excluded from the study (*n* =10). Two additional participants who did not finish the study were excluded from the analysis.

A total of 71 participants met all the inclusion criteria; 37 young adults and 34 older adults. Participants ranged from 17 to 24 years old (*M* = 19.54 years, *SD* = 1.56) in the young adult group and ranged from 65 to 84 years old (*M* = 73.91, *SD* = 6.53) in the older adult group. The number of years of education among all participants ranged from 11 to 25 years (*M* = 14.74, *SD* = 2.69). The older adults had more years of education [$t(69) = -3.62$, $p = .001$)] than young adults (see Table 2 for demographic descriptive statistics). Forty-six (65%) of the participants were female. For the majority of participants (66%), English was their native language. Approximately 42% of participants self-identified their ethnicity as European or North American, 12% were East Asian such as Chinese, 10% were West Asian from the Middle East, 25% were South Asian such as Indian, 5% were African, and the rest endorsed belonging to an “other” ethnic category. There was no difference in gender composition, $\chi 2(1) = .26$, $p = .61$, and general cognitive functioning as measured by the MoCA $t(69) = -1.44$, $p = .16$ between young and older adults. There was no difference in the number of words recalled during the immediate trials of the HVLT-R between older and young adults, $t(69) = 0.77$, $p = .442$, however, there was a difference in their z score according to age-based normative data, $t(69) = -4.35$, $p < .001$. Young adults had a lower z score compared to older adults. There were more native English speakers in the older adult group compared to young adult group, $\chi 2(1) = 5.10$, $p = .024$. There was also a difference between young and older adults in their English fluency, $t(69) = -8.59$, $p < .001$ and in their vocabulary score as predicted by the NAART, $t(69) = -8.93$, $p < .001$. Older adults scored higher on the NAART and had a higher predicted vocabulary score. Young adults endorsed greater symptoms of anxiety, $t(69) = 4.65$, $p < .001$, and depression, $t(69) = 2.22$, $p = .03$, than older adults. When asked to rate their stress from 1-10, young participants gave a higher stress rating than older participants, $t(69) = 3.89$, $p < .001$.

Table 2

Participant Demographics

	Young Adults M (SD)	Older Adults M (SD)
Age in Years	19.54 (1.56)	73.91 (6.53)
Years of Education	13.72 (1.25)	15.85 (3.35)
Percentage of Females	67%	62%
Percentage of Native English Speakers	54%	79%
MoCA Score	26.35 (1.92)	27.03 (2.05)
HVLT-R Total Recall	24.57 (3.18)	23.82 (4.82)
HVLT-R Total Recall Z-Score	-1.31 (0.86)	-0.41 (0.87)
NAART Score	34.11 (7.16)	48.21 (6.62)
Predicted Vocabulary Score	11.39 (1.24)	13.99 (1.21)
HADS Anxiety Score	7.32 (2.86)	4.50 (2.18)
HADS Depression Score	4.05 (3.10)	2.59 (2.39)
Stress Rating	4.70 (2.07)	2.96 (1.68)

Note. MoCA is the Montreal Cognitive Assessment (Nasreddine et al., 2005); HVLT-R is the Hopkins Verbal Learning Test-Revised (Benedict, Schretlen, Groninger, & Brandt, 1998); NAART is the North American Adult Reading Test (Blair & Spreen, 1989); HADS is the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983)

Measures

The Hospital Anxiety and Depression scale (HADS) was used to assess symptoms of depression and anxiety. In this self-report measure, participants were asked to report the frequency and severity in which they experience different symptoms. Meta-analyses indicated that the HADS has high reliability and validity for assessing depression and anxiety in clinical and general populations (Bjelland, Dahl, Haug, & Necklemann, 2002; Herrmann, 1997). HADS also demonstrated good homogeneity and test-retest reliabilities and predictability in young and older adults (Flint & Rifat, 2002; Haworth, Moniz-Cook, Clark, Wang, & Cleland, 2007; Mykletun, Stordal, & Dahl, 2001; Spinhoven et al., 1997).

The Montreal Cognitive Assessment (MoCA) is a screening tool for overall cognitive functioning. The MoCA assesses orientation, naming ability, short-term memory, episodic long term memory, attention, and language ability. The purpose of using MoCA in this study was to eliminate older adults with significant cognitive impairments. Research has demonstrated that the MoCA has adequate psychometric properties as a screening measure for detecting mild cognitive impairment or dementia (Hoops et al. 2009; Mitchell & Malladi, 2010; Nasreddine et al., 2005).

The Hopkins Verbal Learning Test-Revised (HVLT-R) is a clinical measure of learning and memory recall. Participants were given three trials to learn a list of 12 words and asked to recall it immediately after the examiner read the words. After the third learning trial, a delay of 20 minutes was given before participants are asked to recall the word list. The HVLT-R was used in this study to screen for individuals with significant memory difficulties that would negatively impact their performance on the switching task and to screen out older adults with mild cognitive impairment and dementia. Studies have shown that the HVLT-R has high sensitivity and specificity for memory difficulties in dementia (Aretouli & Brandt, 2010; Hogervorst et al., 2002; Shapiro, Benedict, Schretlen, & Brandt, 1999).

The North American Reading Test (NAART) is a measure of language fluency and predicts verbal intelligence. Participants were presented with a card of words and instructed to read each word aloud. The number of incorrectly pronounced words was recorded. The NAART is highly correlated with reading ability and intelligence in the normal population (Strauss, Sherman, & Spreen, 2006). Given that the verbal switching task used in the study requires adequate language fluency and verbal knowledge for word syllables and vocabulary, individuals with lower than average vocabulary levels as predicted by the NAART were excluded.

Experimental Computer Tasks

Switching paradigm. Switching between different operations on a set of stimuli involves retrieval of a task set on each trial, disengaging from the irrelevant task set, and actively engaging in the relevant task set (Miyake et al., 2000). The time required to complete the executive control processes necessary to switch from one task to another includes selection from long-term memory and the configuration in working memory of the appropriate processing algorithms and the inhibition of previously used processing algorithms (Gunning-Dixon & Raz, 2003). Research shows that participant’s reaction times slow down when the participant encountered the same stimuli as a previous task, but was required to respond differently because of negative priming of previously learned stimulus response bindings (Hübner, Kluwe, Luna-Rodriguez, & Peters, 2004; Wylie & Allport, 2000). Similarly, switches to a task that has been abandoned only two trials earlier show longer reaction times than switches to a task that been abandoned less recently, because of the greater residual inhibition associated with the more recently abandoned set (Mayr, 2001; Mayr & Kliegel, 2003). These findings suggest that inhibitory control plays a role in reducing interference from irrelevant dimensions of the task during task shifting.

This present study used a forced, cued-based computerized switching paradigm. In each paradigm, participants switched between two different tasks with two possible responses. These two tasks were adapted from a study by Kray and Lindenberger (2000) because the tasks showed comparable performance levels during switching trials separately for young and older adults. In the visual switching paradigm, participants decided whether the figure was a triangle or a rectangle (Task A), or whether the figure was coloured or grey (Task B); see Table 3 for the switching paradigm tasks. There were a total of 30 figures; half triangles and half rectangles of different colours (red, blue, green, yellow, orange, turquoise, brown, violet) or different grey tones (ranging from light grey to black). The visual switching paradigm included 26 trials of Task A and 26 trials of Task B. Participants were asked to switch 15 times between tasks. Twenty stimuli were repeated for a different task operation at two rates: half that occurred two trials ago and half that occurred more than four trials ago.

In the verbal switching paradigm, participants decided whether a word (e.g., dog) was an animate or inanimate object (Task A), or whether the number of syllables in the word was one or two (Task B); see Table 3 for the switching paradigm tasks. There were a total of 48 words with four attribute combinations: (a) animate-one syllable, (b) animate-two syllables, (c) inanimate-one syllable, and (d) inanimate-two syllables. The verbal switching paradigm consisted of 31 trials of Task A and 30 trials of Task B. Participants were asked to switch 16 times between tasks. Twenty stimuli were repeated for a different task operation in two varying rates: half that occurred two trials ago and half that occurred more than four trials ago.

Table 3

Switching Paradigm-Stimulus Materials and Task Set

Stimulus Materials	Example Items	Task Sets	Response Options	
Figures	Red rectangle	Colour	Grey shade	Coloured
		Form	Triangle	Rectangle
Words	Dog	Category	Inanimate	Animate
		Syllables	One	Two

The response keys for the two switching tasks were different and clearly labeled on the computer (see Figure 1 for the computer keys). The ‘inanimate’ labeled key is for inanimate object words and the ‘animate’ labeled key is for animate object words. The ‘1’ labeled key is for one-syllable words and the ‘2’ labeled key is for the two-syllable words. The triangle-shape labeled key is for triangle figures and square-shape labeled key is for rectangular figures. The ‘black’ labeled key is for grey shaded figures and the ‘rainbow’ labeled key is for coloured figures.

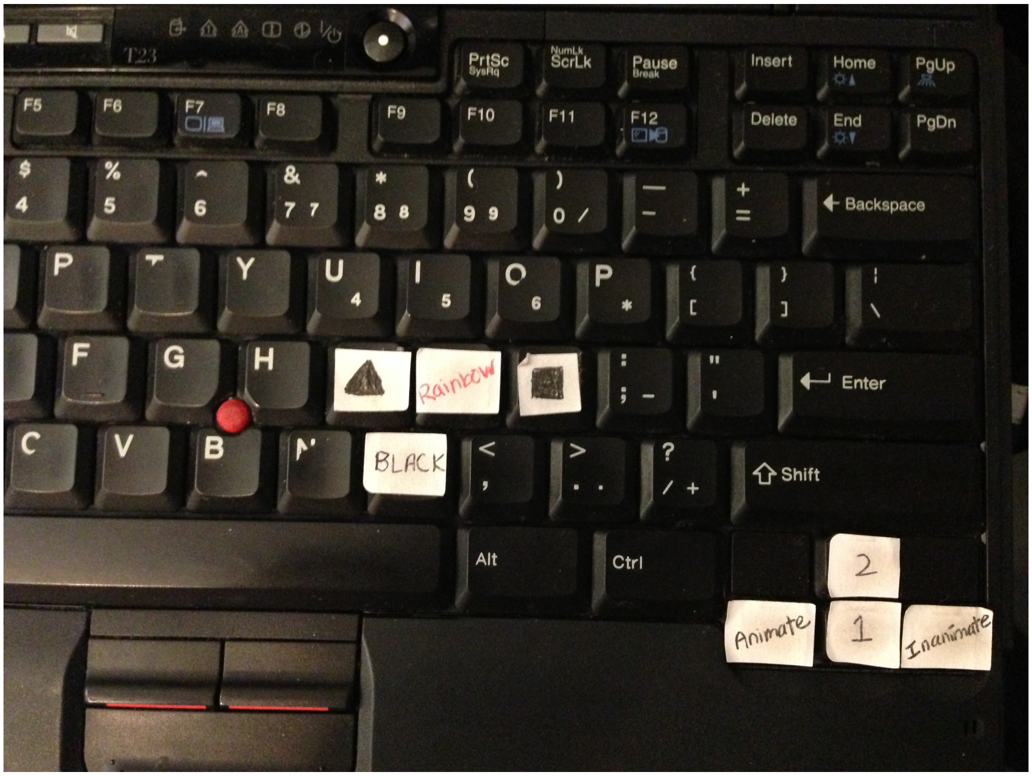

Figure 1. Switching paradigm response keys.

Research shows that mood induction generally lasts for a short period of time before mood regulation occurs (Isen & Gorgoglione, 1983; Kliegel et al., 2005). Therefore, the timing of cognitive tasks must be brief following mood induction in order to maximize mood effect. Both switching paradigms were usually completed within five minutes because research shows that mood inductions only last for about five minutes (Isen & Gorgoglione, 1983; Kliegel et al., 2005). For half of the participants, stimuli shown at the top half of the screen indicated participants should follow task A instructions whereas stimuli shown at the bottom half of the screen indicated that participants should follow task B instructions. For the other half of participants, the top half of the screen was for task B and bottom half of the screen was for task A. Participants completed both the visual and verbal switching tasks, one after the other. The order of visual and verbal switching tasks was counterbalanced.

Simple Reaction Time. In the simple reaction time task, participants saw a cross in the middle of the computer screen for variable lengths of time (between 500 and 2500 milliseconds) before the letter O was shown on the screen. Participants were asked to press the space bar as quickly as possible when the letter O was shown on the screen. A total of 20 trials were given and the average reaction time for the last 15 trials was used as a measure of participants' general processing speed.

N-back Task. In this task, participants were shown letters one at a time on the computer screen and they decided whether each letter was the same as the one shown two trials ago. Participants had to continuously remember the last two letters they saw in order to accurately decipher if the current letter was the same as the one they saw two trials ago. The number of errors was used to measure participants working memory capacity. The task included a total of 58 trials with 15 target trials.

Mood Induction

Films and music were used as mood-inducing stimuli because previous meta-analyses revealed that films and music are the most effective for inducing positive and negative emotions (Gerrads-Hesse, Spies, & Hesse, 1994; Westermann, Spies, Stahl, & Hesse, 1996). The film clips and music pieces used in this study have been found to elicit high happiness and sadness (Chu & Abeare, 2011; Gross & Levenson, 1995; Hagemann et al., 1999; Hewig et al., 2005; Mayer, Allen, & Beauregard, 1995; Tsai et al., 2000). The film clips and music pieces were presented on an IBM® laptop with Bose® headphones.

Positive mood was induced with a clip from the movie When Harry Meet Sally (Reiner, 1989), where a man and woman sit in a restaurant talking to each other, and then the woman leans back and starts to show signs of sexual arousal while other customers are watching. Negative mood was induced with a clip from the movie The Champ (Lovell & Zeffirelli, 1979). In the clip, a boxer is lying severely injured on a table, when his little son enters. Neutral mood was induced with a clip from the movie Hannah and Her Sisters (Greenhut, Joffe, Rollins & Allen, 1986). In the clip, two women stroll through the shopping centre talking. Participants in the positive-negative group were shown a positive booster mood film clip at the end from the movie An Officer and a Gentleman (Elfand, Stewart & Hackford, 1982). In the clip, a man strides through a factory, meets a woman and gives her a kiss, and then they embrace he sweeps her in his arms and carries her out of the factory. The volume was set at a medium level while participants were watching the film. Following the mood clip, mood congruent music was played while participants were completing the shifting tasks. Music was chosen as previous research found that it maintains mood inductions (Gerrads-Hesse et al., 1994). The positive inducing music was Delibes (1870) Mazurka from Coppelia. The negative inducing music was Chopin (1839) Largo from Preludes. The neutral music was Holst (1915) Neptune-the Mystic from The Planets. Given the variability in individual detection of sound loudness, the researcher helped each participant to adjust volume level of the music in order for the music to be heard as playing softly in the background.

Mood Assessment

After the mood inductions, participants' mood was checked to determine whether the mood manipulation worked. Several past studies did not check the effectiveness of the mood induction at all or only checked for change in mood after induction. Measuring mood only after induction does not necessarily indicate a mood change, studies need to measure mood prior to and after mood induction to ensure a real mood change has occurred. Research suggests that there is no clear objective way to measure the experience of emotion using any single measurement or profile of measurements, but Barrett (2006) suggested that verbal self-report might be the only means of assessing the experience of emotion and self-report is also the most commonly used mood measure. Participants reported their mood using a self report questionnaire using a 9-point Likert scale with four adjectives: refreshed vs. tired, calm vs. anxious, alert vs. unaware, positive vs. negative, approach vs. withdraw (adapted from Oaksford et al., 1996; see Appendix A). This self-report questionnaire is a quick assessment that measures mood valence, arousal, and motivation, aspects of mood consistent with the dimensional view of emotions. The lower end of the scale indicates more positive feelings while the higher end of the scale represents more negative feelings. The mood ratings were added together to produce a final score. Therefore, lower scores indicated a more positive mood and higher scores indicated a more negative mood.

Computer Task Questionnaire

Research demonstrates that the relationship between mood and cognitive functioning is affected by different variables such as internal or external motivation and level of task interest. Yet most studies examining mood and executive function performance do not to take these factors into account. Studies have found that motivation and task interest can fluctuate over the course of the study because an individual's experience of performing a cognitive task can change their level of motivation. Motivation, task interest, and task enjoyment, as well as effort, were measured using self-report after each switching task using the computer task questionnaire (see Appendix B).

Table 4

Study Procedure

1. Complete the consent process, including reading and signing the written consent form
2. Fill out demographic questionnaire
3. Complete the HADS
4. Rate mood
5. Administer the MoCA
6. Do control components of the switching task and then practice doing switching task
7. Watch neutral mood inducing film and then rate mood
8. Listen to neutral music while performing switching paradigm
9. Complete task questionnaire
10. Administer the NAART
11. Complete the simple reaction time task
12. Watch either a positive or negative mood inducing film (e.g. positive for positive-negative group; negative for negative-positive group)
13. Rate mood
14. Perform switching task while listening to mood inducing music
15. Complete task questionnaire
16. Administer HVLT-R immediate recall trials
17. Complete questionnaires
18. Do the N-back task
19. Administer HVLT-R delay recall trial
20. Watch either a positive or negative mood inducing film (e.g. negative for positive-negative group; positive or negative-positive group)
21. Rate mood
22. Perform switching task while listening to mood inducing music
23. Complete task questionnaire
24. Rate mood
25. Debrief and receive compensation for participating

Note. HADS is the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983); MoCA is the Montreal Cognitive Assessment (Nasreddine et al., 2005); NAART is the North American Adult Reading Test (Blair & Spreen, 1989); HVLT-R is the Hopkins Verbal Learning Test-Revised (Benedict, Schretlen, Groninger, & Brandt, 1998)

Procedure

In order to maintain consistency across participants, one IBM® computer laptop and a set of Bose® headphones was used for all participants. All computerized tasks (control tasks, switching paradigm, N-back task, and simple reaction time task), film clips and music were presented on the same IBM® laptop. Therefore, each participant partook in the study individually. Young adults participated in a laboratory at the University of Toronto, Scarborough campus. Older adults participated in a laboratory at Baycrest Hospital, Psychology department. Both laboratories were set up in a similar fashion with a small desk and two chairs. The procedure of the study is shown in Table 4. First, participants completed a written informed consent form. The consent form described the purpose of the study, the overall procedure of the study, the risks and benefits of completing the study, the anonymity and voluntary nature of the study as well as the compensation provided for participating. Participants were then assigned participant identification numbers and asked to fill out all paperwork using their assigned number rather than their real name to maintain anonymity. Next, participants filled out a demographic questionnaire and the HADS. Participants were also asked to rate their current mood using a self-report questionnaire, which was used as an indicator of their baseline mood prior to any mood inductions (see Appendix A). Then the researcher administered the MoCA. Participants then completed the control component tasks of the switching paradigm on the laptop computer. In these control tasks, participants performed each task of the switching paradigm separately. The first task was deciding whether each word represented an animate or inanimate object. Secondly, they decided how many syllables were present in each word. Next, participants were shown coloured objects and determined whether the shape is a triangle or rectangle. In the last control task, participants determined whether the object was coloured or grey.

After completing all four control tasks, participants completed a practice trial for the switching paradigm on the computer. During these practice trials, the switching task was introduced and participants were given feedback on the screen if they responded incorrectly. The practice trials were performed under guidance from the examiner until the participant understood how to complete the task (i.e. responded correctly to three trials). Then the participant was shown the neutral mood-inducing film on the laptop using headphones and asked to rate their mood. Next, participants completed the switching paradigm on the computer while listening to neutral music through the headphones. Following the switching task, participants completed the computer task questionnaire in which they were asked to rate their task interest, motivation, and effort regarding the computer switching task (see Appendix B). As a distractor task, participants completed the NAART and a simple reaction time task to let the mood induction fade. Older participants were given the opportunity to take a five-minute break if they wished to do so. During the break, participants either made conversation with the researcher, took a washroom break, or walked down the hallway. Then participants were induced to experience either a positive or negative mood using a film clip. Half of the participants were induced to experience a positive mood first (positive-negative group, n= 31) and half were induced in a negative mood first (negative-positive group, n = 40). After watching the film, participants rated their mood before performing the switching paradigm while listening to mood congruent music. Again, participants completed the computer task questionnaire. Following the task questionnaire, participants were given the HVLT-R immediate recall trials. During the time between immediate and delayed recall, participants completed questionnaires not related to this study. Older participants were again given the opportunity to take a five-minute break. Then, the N-back task was administered to participants before completing the HVLT-R delayed recall trial. Following the HVLT-R, participants were induced to the other mood (either positive or negative) and completed the switching paradigm while listening to mood congruent music. The computer task questionnaire was completed following the switching task. For those participants in the positive-negative group in which a negative mood was recently induced, a positive mood induction film was shown to improve the mood of participants. Finally, participants were asked to report their current mood one last time using the self-report questionnaire and then were debriefed about the study and provided with compensation. Young participants were provided with course credits for participation and older participants were provided with transportation costs (either parking fee or bus tokens).

Chapter III

Results

Data were analyzed with a 2 (older vs. young) x 3 (neutral, happy, sad mood induction) mixed factorial ANOVA on each switching performance measure (switch cost, decision errors, and switch errors). Planned simple comparisons were used to determine if differences exist for performance measures between neutral, positive, and negative mood inductions. A two-tailed critical alpha value of 0.05 was used.

Mood Manipulation Check

A mixed ANOVA was conducted to determine if the mood manipulation was effective with a 2 (older vs. young) x 5 (pre mood induction, neutral mood induction, happy mood induction, sad mood induction and end of the study) analyses to compare mood ratings at the beginning of study and mood ratings made following mood inductions between young and older adults. Mauchley's test indicated that the assumption of sphericity was violated, $\chi 2(9) = 50.28$, $p < .05$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimate of sphericity ($\varepsilon = .72$). Observed power ranged from 0.25 to 1.00. There was a main effect for mood, $F(2.90, 199.84) = 23.63$, $p < .001$, partial eta square = .26. Simple contrasts showed that the mood induction worked because participants rated their mood as more negative after the negative mood induction compared to their ratings at the beginning of the study, $F(1, 69) = 33.23$, $p < .001$, partial eta square = .33; see Figure 2 for mood ratings in older and young adults. Participants also rated their mood as more positive after the positive mood induction compared to their ratings at the beginning of the study, $F(1, 69) = 12.95$, $p = .001$, partial eta square = .16. There was no significant difference in mood ratings at the beginning of the study and mood ratings after the neutral film, indicating there was no change in mood after the neutral film, $F(1, 69) = 1.66$, $p = .20$, partial eta square = .02, There was also no significant difference between mood ratings at the beginning of the study and at the end of the study, $F(1, 69) = .02$, $p = .88$, partial eta square < .01; see Table 5 for mood ratings in young and older adults.

There was also a main effect of age group, $F(1, 69) = 13.24$, $p = .001$, partial eta square =.16. Older adults rated their mood as more positive before the mood induction, $t(69) = 4.10$, $p < .001$, partial eta square = .20, after the neutral mood induction, $t(69) = 2.44$, $p =.017$, partial eta square = .08, after the positive mood induction, $t(69) = 4.32$, $p < .001$, partial eta square = .21, and at the end of the study, $t(69) =4.19$, $p < .001$, partial eta square = .20. This is consistent with the previous studies showing that older adults rated their mood as more positive than young adults. However, there was no significant difference in the mood ratings of young and older adults after the negative film, *t*(69) =1.32, *p* = .19, partial eta square = .03. There was also no significant interaction between age group and mood ratings, *F*(2.90, 199.84) = 2.63, *p* = .053, partial eta square = .04

Table 5

Mean Mood Ratings Following Mood Inductions of Young and Older Adults (with Standard Deviations in Parentheses)

	Young Adults	Older Adults
Pre Mood Induction	18.08 (6.83)	11.68 (6.30)
Neutral Mood Induction	18.05 (7.19)	13.41 (8.83)
Positive Mood Induction	16.00 (6.75)	9.94 (4.80)
Negative Mood Induction	21.14 (7.67)	18.38 (9.88)
Final Mood	18.84 (7.00)	11.32 (6.90)

Note. Mood ratings are the average total scores from the mood self report questionnaire.

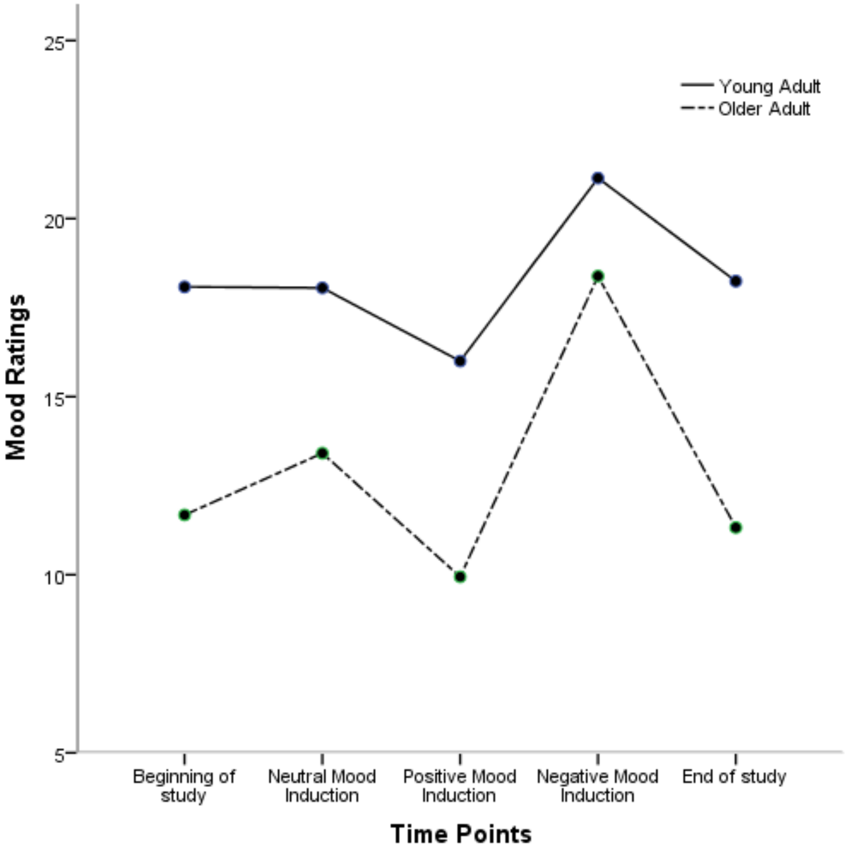

Figure 2. Mood ratings during the experiment for older and young adults.

Control Tasks

A T-test was conducted to examine the difference between young and older adults in their performances on the control tasks. Levene's Test for Equality of Variances was used to determine if variances between the young and older adult groups was equal. All assumption of homogeneity of variance violations were corrected by adjustments to the degrees of freedom using the Welch-Satterthwaite method. Differences were found in the reaction times for the shape task, $t(60.41) = -4.71$, $p < .001$, $r = .52$, and the colour task $t(50.70) = -5.69$, $p < .001$, $r = .62$. Older adults took longer to complete these tasks (see Table 6 for average reaction times and errors). There was no difference between young and older adults in the reaction time for the syllables task, *t(*69)= -1.53, *p* = .13, *r* = .18, or animate/inanimate task, *t(*69)= -0.49, *p* = .63, *r* = .06. When examining the number of errors made, there was no difference between groups in the animate/task, *t(*69)= 0.34, *p* = .74, *r* = .04, syllables task, *t(*69)= -1.12, *p* = .27, *r* = .13, or shape task, *t(*68.95)= 1.58, *p* = .12, *r* = .19. Older adults made more errors in the colour task, *t*(51.10)= -4.02, *p* = .00, *r* = .49.

Table 6

Average Reaction Times (RT) And Number of Errors During Control Tasks for Young and Older Adults (with Standard Deviations in Parentheses)

Control Task		Young Adults	Older Adults
Animate/Inanimate	RT	1030.34 ms (301.97)	1145.85 ms (332.37)
	Errors	1.51 (1.39)	1.41 (1.10)
Number of Syllables	RT	1298.93 ms (463.63)	1357.72 ms (543.56)
	Errors	2.43 (2.81)	1.76 (2.13)
Shape	RT	610.67 ms (145.91)	806.20 ms (197.77)
	Errors	0.43 (0.55)	0.24 (0.50)
Colour	RT	849.68 ms (246.41)	1338.82 ms (442.65)
	Errors	0.70 (1.10)	2.24 (1.95)

Switching Analyses

Switching cost was measured by subtracting reaction time (RT) on non-switch trials in switching conditions from RT on switch trials in switch conditions. Participant errors were examined for switch errors, which are failures to switch between tasks (e.g. indicating number of syllables when task was to determine shape) and decision errors, which are selecting the wrong response within a correct task set (e.g. deciding an animal as inanimate).

Neutral mood. One way ANOVA was conducted to examine the difference between young and older adults in their performances on the switching paradigm following neutral mood induction with age group as a between subjects variable and switch cost, decision errors, switching errors for visual and verbal switching task as dependent variables. Levene's Test for Equality of Variances was used to determine if variances between the young and older adult groups was equal. All assumption of homogeneity of variance violations was corrected by adjustments to the degrees of freedom using the Welch method. In the verbal switch task, no differences between age group were found in switch cost, $F(69)= 2.92$, $p =.092$, $r = .20$, number of decision errors, F(35.87) = 1.15, $p = .244$, $r = .18$, or number of switch errors, $F(36.49) = 2.96$, $p = .106$, $r = .27$. For the visual switch task, there was no difference between young and older adults in the switch cost, $F(69)= 2.73$, $p =.103$, $r = .20$, but older and young adults differ in the number of decision errors, $F(33.75) = 7.06$, $p = .016$, $r = .42$ and number of switch errors, $F(35.36) = 4.75$, $p = .044$, $r = .34$. Older adults made a greater amount of errors than young adults (see Table 7 for switching performance means and standard deviations among young and older adults).

Comparison between mood inductions. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was conducted to examine differences between specific switching performance measures (switch cost, decision errors, switch errors) after mood induction (neutral, positive and negative mood) as within subject variables and between age groups (young and older adults) as a between subject variable. Given that violation of sphericity can produces biases in the F-tests, Bonferroni correction was used to control for Type 1 error rate. Simple contrasts were used to examine the difference between negative and neutral moods, and between positive and neutral moods. When the assumption of sphericity was violated, the degrees of freedom were corrected using Greenhouse-Geisser estimate of sphericity. A T-test examining performance difference between negative-positive order and positive-negative order among all participants found no difference in switching performance, indicating no order effects.

Verbal switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was conducted on verbal switch cost. There was no main effect for mood condition, $F(2, 138) = .74$, $p = .48$, $r = .007$, or age group, $F(1, 69) = 1.44$, $p = .23$, $r = .14$. There was no interaction between age group and mood condition, $F(2, 138) = 1.08$, $p = .34$, $r = .09$. The same analysis was done on decision errors and there was no main effect for mood condition, $F(1.07, 73.99) = 0.76$, $p = .40$, $r = .10$, age group $F(1, 69) = 0.57$, $p = .45$., $r = .09$, or interaction between mood condition and age group, $F(1.07, 73.99) = 1.88$, $p = .16$, $r = .16$. Similarly for the number of switch errors, there was no main effect for mood, $F(1.37, 94.78) = 1.94$, $p = .16$, $r = .14$, or age group, $F(1, 69) = .071$, $p = .40$, $r = .03$. There was a significant interaction between mood condition and age group, $F(1.37, 94.78) = 3.56$, $p = .049$, $r = .19$; see Table 7. Young adults made a similar amount of switch errors across mood inductions whereas older adults made fewer errors following positive and negative mood inductions compared to neutral mood (see Figure 3). Overall observed power for verbal switch task analyses ranged from .116 to .541 ($M = .24$).

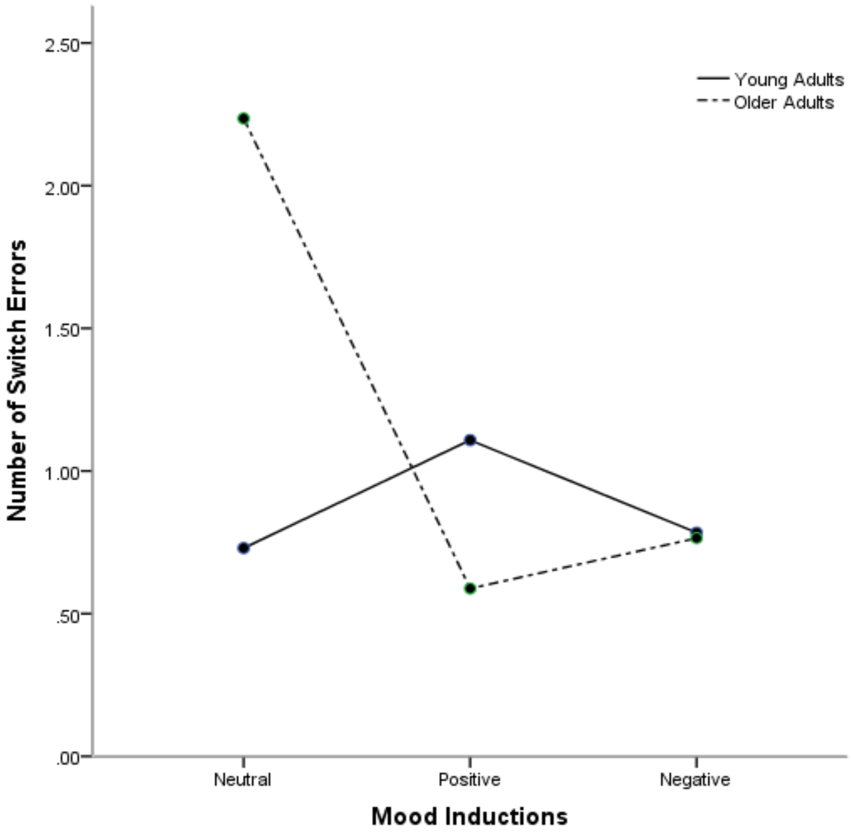

Figure 3. Switching errors in the verbal switch task following mood inductions for young and older adults.

Table 7

Young and Older Adults Switching Performance Across Mood Inductions (with Standard Deviations in Parentheses)

Verbal Switch Task	Neutral Mood	Positive Mood	Negative Mood
Switch Cost			
Young Adults	397.77 ms (250.59)	455.83 ms (296.78)	439.98 ms (265.22)
Older Adults	529.91 ms (391.66)	534.57 ms (405.00)	458.52 ms (337.18)
Decision Errors			
Young Adults	2.08 (2.29)	2.41 (2.54)	2.70 (2.12)
Older Adults	4.26 (10.53)	2.21 (2.31)	2.41 (2.41)
Switching Errors			
Young Adults	0.73 (1.24)	1.11 (1.98)	0.78 (1.20)
Older Adults	2.24 (5.16)	0.59 (1.28)	0.76 (1.89)
Visual Switch Task			
Switch Cost			
Young Adults	369.49 ms (272.16)	295.28 ms (255.36)	281.16 ms (213.77)
Older Adults	537.83 ms (551.40)	201.60 ms (278.72)	286.64 ms (249.76)
Decision Errors			
Young Adults	0.84 (1.14)	0.81 (1.15)	1.30 (1.73)
Older Adults	5.35 (10.27)	4.12 (8.57)	2.44 (4.24)
Switching Errors			
Young Adults	0.54 (0.93)	1.22 (1.90)	1.03 (1.59)
Older Adults	2.26 (4.72)	1.09 (3.55)	0.71 (1.80)

Visual switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was performed on the visual switch cost, there was a main effect for mood condition, $F(1.35, 93.05) = 8.93$, $p = .001$, $r = .30$. Contrasts indicated that in general participants had a reduced switch cost in a positive mood ($M = 248.43$, $SD = 31.69$) compared to neutral mood ($M = 453.67$, $SD = 50.96$), $t(62.36) = 205.\ 23$, $p = .005$, $r = 0.99$. Participants also had a reduced switch cost in a negative mood compared ($M = 283.84$, $SD = 27.52$) to neutral mood, $t(57.89) = 169.77$, $p = .014$, $r = 99$. There was no difference between positive and negative moods in their switch cost, *t(*29.13) = 35.46, *p* = .68, *r* = .99. There was no main effect for age group, *F*(1, 69)= 0.32, *p* = .57, *r* = .07. Although the interaction between age group and mood condition did not reach significance, *F*(1.35, 93.05) = 3.25, *p* = .06, *r* =.18, there was a trend indicating that young adults performed similarly between positive and neutral moods whereas older adults performed better in a positive compared to neutral mood; see Table 7.

A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was done in the number of decision errors. The main effect for mood condition was not significant, *F*(1.59, 109.93) = 1.50, *p* = .23, *r* = .12. A main effect for age group was significant, *F*(1, 69) = 7.70, *p* = .007, *r* = . 32. Older adults made more decision errors than young adults, *t(*1.08) = 2.99, *p* = .007, *r* = .94; see Table 7. The interaction between mood condition and age group did not reach significance, *F(*1.59, 109.93) = 2.91, *p* = .07, *r* = .16, but there was a trend for young adults to make similar number of errors whereas older adults made fewer errors in a negative mood to neutral mood.

A similar analysis was done for the number of switch errors, no main effect for mood condition, *F(*1.80, 124.31) = 1.10, *p* = .33, *r* = . 09, or age group, *F(*1, 69) = 0.76, *p* = .39, *r* = .10, was found. There was a significant interaction between mood condition and age group, *F(*1.80. 124.31) = 4.87, *p* = .012, *r* = .19. Generally, older adults made fewer switch errors following positive and negative mood inductions compared to neutral mood induction whereas young adults made more switch errors in positive mood compared to neutral mood and no difference between negative and neutral moods (see Figure 4). Overall observed power for visual switch task analyses ranged from .087 to .909 (*M* = 0.46).

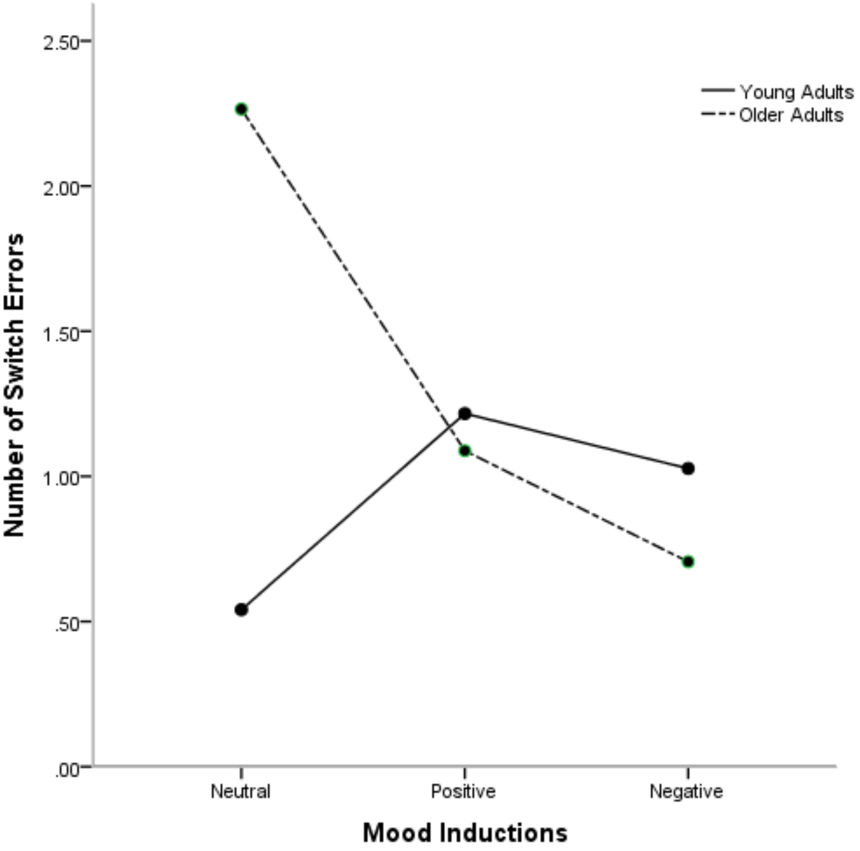

Figure 4. Switching errors in the visual switch task following mood inductions for young and older adults.

ANCOVA. Given that working memory and processing speed have been found to affect set switching performance in older adults, these variables were entered as covariates in an ANCOVA. The same previously mentioned 2 (age group) x 3 (mood condition) mixed factorial ANOVA was performed with the average reaction time in the reaction time task and the number of errors in the N-back task entered as covariates.

*Verbal switch task***.** A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was performed for the verbal switch cost with covariates, there was no main effect for mood condition, *F(*2, 134) = 2.00, *p* = .14, *r* = .12, or age group, *F(*1, 67) = 0.32, *p* = .576, *r* = .07. There was no interaction between mood condition and reaction time, *F(*1, 67) = 2.16, *p* = .119, *r* = .18, or mood condition and N-back errors, *F(*1, 67) = 0.07, *p* = .931, *r* = .032. There was also no interaction between age group and mood condition, *F(*2, 134) = 0.34, *p* = .712, *r* = .05.

A similar analysis was done for decision and switch errors, there was no main effect for mood condition, *F(*1.07, 71.89) = 0.23, *p* = .648, *r* = .05, or age group, *F(*1, 67) = 0.42, *p* = .517, *r* = .08, or interaction between mood condition and age group, *F(*1.07, 71.89) = 2.46, *p* = .119, *r* = .018 for decision errors. No interactions were found between mood condition and the covariates of reaction time, *F(*1.07, 71.89) = 0.02, *p* = .897, *r* = .017, and N-back errors, *F(*1.07, 71.89) = 0.87, *p* = .119, *r* = .109 for decision errors. There was no main effect for mood condition, *F(*1.37, 92.01) = 0.20, *p* = .732, *r* = .05, or age group, *F(*1, 69) = 0.07, *p* = .40, *r* = .03, in switch errors. There was no interaction for mood condition and reaction time, *F(*1.37, 92.01) = 0.18, *p* = .749, *r* = .044, or mood condition and N-back errors, *F(*1.37, 92.01) = 1.95, *p* = .161, *r* = 144. However, there was a significant interaction between mood condition and age group, *F(*1.37, 92.01) = 4.28, *p* = .029, *r* = .21; see Figure 5. After taking into account covariates, young adults made a similar amount of switch errors across mood inductions whereas older adults made fewer errors during positive and negative mood inductions compared to neutral mood; see Table 8 for the means and standard errors for switch errors after accounting for covariates. Overall observed power for verbal switch task analyses ranged from .053 to .602 (*M* = .20).

Table 8

Young and Older Adults Average Switch Errors for Verbal Switch Task Across Mood Inductions with Standard Errors and Confidence Intervals

Group	Mood	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Young Adults	Neutral	.703*	.632	-.559	1.965
	Positive	.941*	.253	.436	1.446
	Negative	1.218*	.285	.649	1.787
Older Adults	Neutral	2.264*	.661	.944	3.584
	Positive	.594*	.265	.066	1.122
	Negative	.469*	.298	-.126	1.063

Note. *The number of switch errors following mood inductions are estimates after taking into account the covariates of average reaction time = 449.37 and N-back task errors = 4.80.

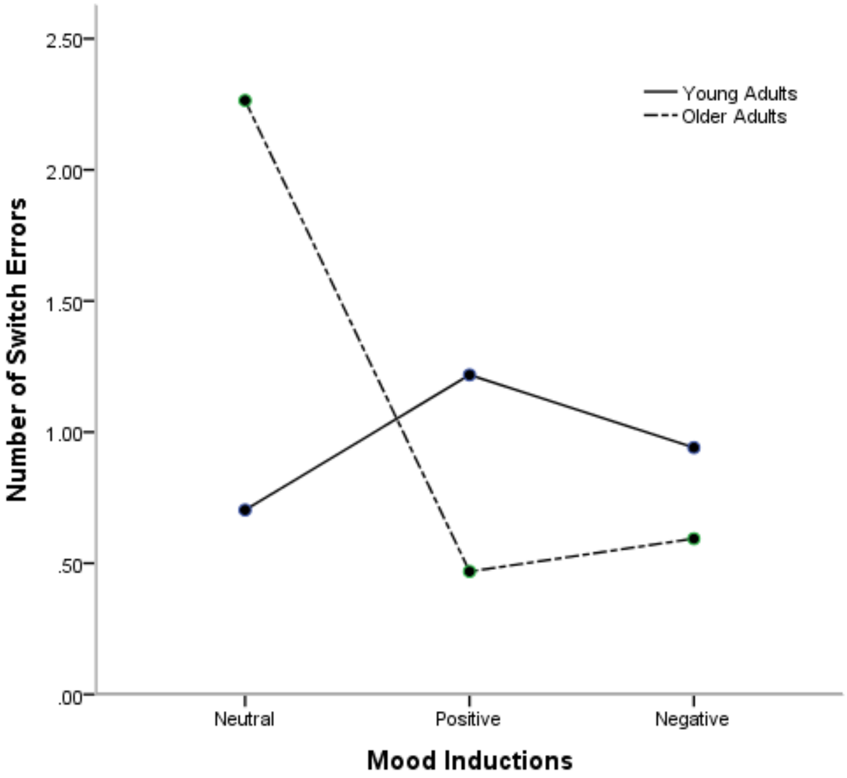

Figure 5. Switching errors in the verbal switch task following mood inductions after controlling for covariates for young and older adults. The number of switching errors following mood inductions are estimates after taking into account covariates of average reaction time = 449.37 and N-back task errors = 4.80.

Visual switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was performed for visual switch cost with covariates of reaction time and n-back errors. There was no main effect for mood condition, *F(*1.35, 90.70) = 0.34, *p* = .712, *r* = .06, or age group, *F(*1, 67)= 0.201, *p* = .655, *r* = .05, in the visual switch cost. Interactions were not significant for mood condition and reaction time, *F(*1.35, 90.70) = 0.07, *p* = .865, *r* = .027, or for mood condition and N-back errors, *F(*1.35, 90.70) = 0.92, *p* = .367, *r* = .10. The interaction between age group and mood condition almost reached significance, *F(*1.35, 90.70) = 3.51, *p* = .051, *r* = .19. Examining performances, young adults performed similarly between positive and neutral moods whereas older adults performed better in a positive compared to neutral mood; see Table 9 for means and standard errors for visual switch task cost after accounting for covariates.

Table 9

Young and Older Adults Average Switch Cost for Visual Switch Task Across Mood Inductions with Standard Errors and Confidence Intervals

Group	Mood Induction	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Young Adults	Neutral	361.936*	73.370	215.489	508.383
	Positive	301.256*	45.839	209.761	392.751
	Negative	288.360*	39.735	209.049	367.671
Older Adults	Neutral	546.060*	76.745	392.876	699.244
	Positive	195.088*	47.948	99.384	290.792
	Negative	278.800*	41.563	195.840	361.759

Note. *Switch cost following mood inductions are estimates after taking into account the covariates of average reaction time = 449.37 and N-back task errors = 4.80.

Regarding decision errors, 2 (age group) x 3 (mood condition) mixed factorial ANOVA with covariates found a main effect for mood condition, *F(*1.57, 105.22) = 3.95, *p* = .31, *r* = .19. Participants made the most errors in a neutral mood (*M* = 3.06, *SD* = 0.83), fewer errors in a positive mood (*M* = 2.42, *SD* = 0.64) and the fewest errors in a negative mood (*M* = 1.86, *SD* = 0.36) after controlling for covariates. There was no main effect for age group, *F(*1, 67) = 2.30, *p* = .134, *r* = .18. The interaction between mood condition and reaction time, *F(*1.57, 105.22) = 4.62, *p* = .019, *r* = .205, was significant. There was no interaction between mood condition and N-back errors, *F(*1.57, 105.22) = 0.44, *p* = .595, *r* = .065, or mood condition and age group, *F(*1.57, 105.22) = 1.60, *p* = .210, *r* = .12.

The same mixed ANOVA performed in switch errors found a main effect for mood condition, *F(*1.59, 106.38) = 3.68, *p* = .038, *r* = .18. Similar to decision errors, participants made the most errors in a neutral mood (*M* = 4.45, *SD* = 1.14), fewer errors in a positive mood (*M* = 3.56, *SD* = 0.91) and the least number of errors in a negative mood (*M* = 2.71, *SD* = 0.48) after taking into account covariates. No main effect for age group was found in switch errors, *F(*1, 67) = 0.91, *p* = .344, *r* = .12. The interaction between mood condition and reaction time was significant, *F(*1.59, 106.38) = 3.40, *p* = .041, *r* = .18. No interaction was found between mood condition and N-back errors, *F(*1.59, 106.38) = 0.88, *p* = .408, *r* = .091, or between mood condition and age group, *F(*1.59, 106.38) = 2.03, *p* = .146, *r* = .14. General observed power for visual switch task analyses ranged from .059 to 697 (*M* = .33).

Inhibition Analyses

Research suggests that the ability to inhibit plays a role in task shifting because it reduces interference from irrelevant dimensions of the task. In our study, interference from irrelevant dimensions was examined by using repeated stimuli for a different task operation (e.g. see “cow” and asked to do Task A and then see “cow” again but asked to do Task B). Inhibitory control was measured by subtracting reaction time for repeated stimuli that occurred two trials ago (short trials) from reaction time for repeated stimuli that occurred more than four trials ago (long trials). Reduced inhibitory control was defined as greater reaction times on recently repeated trials than previously repeated trials in the switching conditions and making more errors when responding to the repeated trials. A T- test found no difference in inhibition performance between negative-positive order and positive-negative order among participants, suggesting no order effects.

Neutral mood. One way ANOVA was conducted to examine the difference between young and older adults in their performances in their inhibition performance following neutral mood induction with age group as a between subject variable and inhibitory control and errors for visual and verbal switching task as dependent variables. Levene's Test for Equality of Variances was used to determine if variances between the young and older adult groups was equal. All assumption of homogeneity of variance violations was corrected by adjustments to the degrees of freedom using the Welch method. Significant differences between age group were found in inhibitory control, $F(69)= 4.27$, $p =.043$, $r = .24$ and inhibition errors made $F(69) = 4.45$, $p = .038$, $r = .25$ in the verbal switch task. Older adults had a larger switch cost and more errors than young adults (see Table 10 for inhibition performance means and standard deviations among young and older adults). There was also a difference between young and older adults in the switch cost, $F(69)= 9.31$, $p =.003$, $r = .34$, and the number of inhibition errors, $F(33.72) = 8.00$, $p = .010$, $r = .44$, in the visual switch task. Similar to the verbal task, older adults had a larger switch cost and more errors than young adults; see Table 10.

Comparison between mood inductions. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was conducted to examine differences between specific inhibition performance measures (inhibitory control and errors) after mood inductions (neutral, positive and negative mood) as within subject variables and between age groups (young and older adults) as a between subject variable. Given that violation of sphericity can produces biases in the F-tests, Bonferroni correction was used to control for Type 1 error rate. Violations of sphericity were corrected using the degrees of freedom were corrected from Greenhouse-Geisser estimate of sphericity. Simple contrasts were used to examine the difference between negative and neutral moods, and between positive and neutral moods.

Verbal switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA performed for inhibitory control found no main effect for mood condition, *F(*1.57, 108.59) = 1.55, *p* = 215, *r* = .12, or age group, *F(*1, 69) = 1.73, *p* = .193, *r* = .15. The interaction between mood condition and age group was not significant, *F(*1.57, 108.59) = 2.57, *p* = .094, *r* = .15. The same analysis done on errors, there was no main effect of mood condition, *F(*1.22, 83.93) = 1.28, *p* = .281. *r* = .12, or age group *F(*1, 69) = -0.46, *p* = .50, *r* = .08. Interaction for mood condition and age group approached significance, *F(*1.22, 83.93) = 3.54, *p* = .055, *r* = .20. Young adults showed no difference in errors across different moods. Older adults made fewer errors following positive and negative mood compared to neutral mood, with the least amount of errors in a positive mood (see Figure 6). General observed power for verbal switch task analyses ranged from .102 to .506 (*M* = .30).

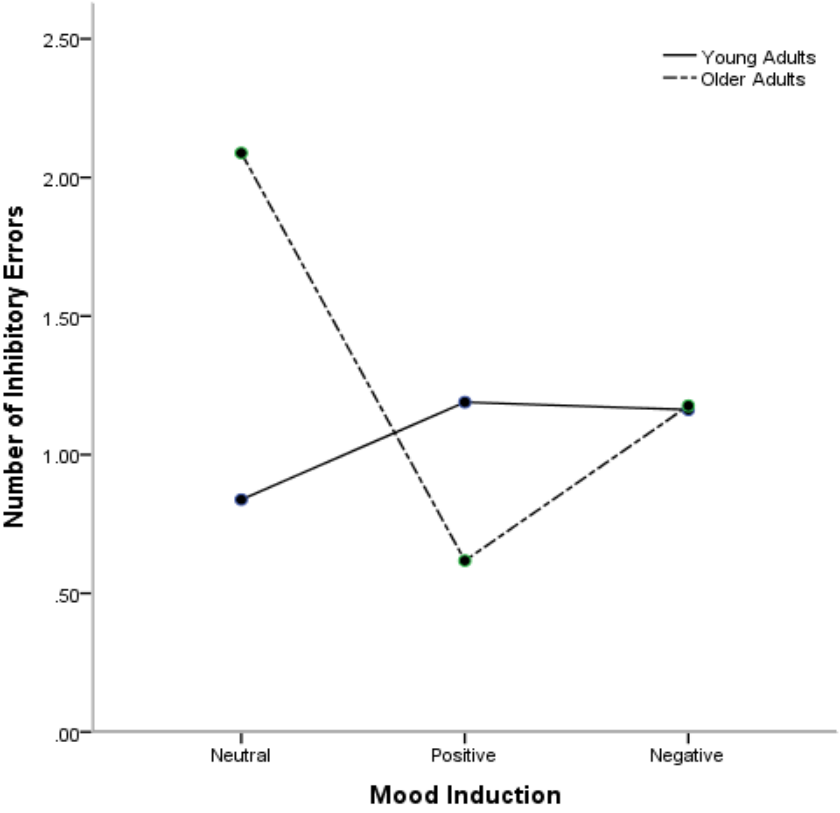

Figure 6. Inhibition errors in the verbal switch task following mood inductions for young and older adults.

Table 10

Young and Older Adults Inhibition Performance Across Mood Inductions (with Standard Deviations in Parentheses)

Verbal Switch Task	Neutral Mood	Positive Mood	Negative Mood
Inhibitory Control			
Young Adults	461.89 ms (405.11)	277.31 ms (529.08)	389.78 ms (383.55)
Older Adults	517.05 ms (449.76)	546.98 ms (570.60)	332.45 ms (365.19)
Inhibition Errors			
Young Adults	0.84 (1.19)	1.19 (1.29)	1.16 (1.14)
Older Adults	2.09 (4.84)	0.62 (0.95)	1.18 (1.42)
Visual Switch Task			
Inhibitory Control			
Young Adults	91.13 ms (396.56)	92.26 ms (460.53)	98.99 ms (368.78)
Older Adults	429.55 ms (533.19)	10.50 ms (302.74)	74.68 ms (370.65)
Inhibition Errors			
Young Adults	0.41 (0.60)	0.78 (1.03)	0.78 (1.25)
Older Adults	2.97 (5.49)	2.09 (4.55)	1.29 (2.36)

Visual switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was done on inhibitory control. A main effect for mood condition in inhibitory control, $F(1.72, 118.92) = 5.05$, $p = .011$, $r = .20$. Participants showed better inhibitory control in a positive mood than neutral mood, $t(82.40) = 208.95$, $p = .04$, $r = .99$, as well as in a negative mood than neutral mood, $t(68.28) = 173.50$, $p = .04$, $r = .85$; see Table 10. Participants also performed better in a positive mood compared to negative mood, $t(58.24) = 35.45$, $p = .04$, $r = .98$. There was no main effect for age group, $F(1, 69) = 2.01$, $p = .161$, $r = .17$. The interaction between mood condition and age group was significant for inhibitory control, $F(1.72, 118.92) = 5.25$, $p = .~009$, $r = .21$. Young adults performances were similar across the different mood inductions whereas older adults performed better following positive and negative mood inductions than neutral mood. Older adults performed best in the positive mood induction (see Figure 7).

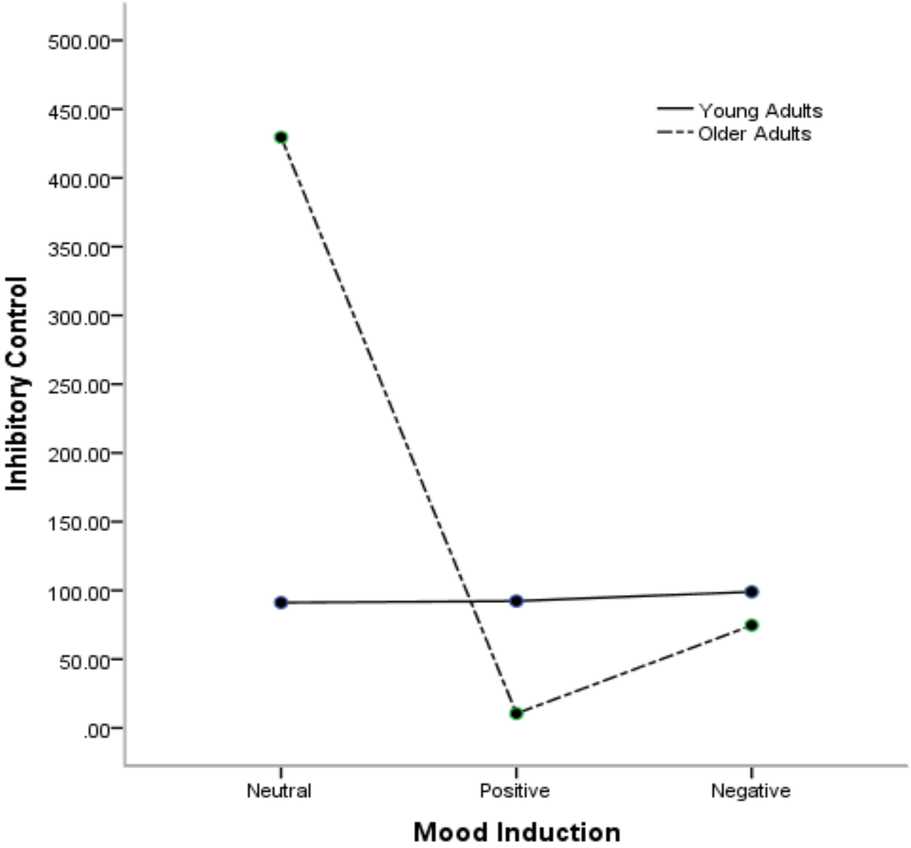

Figure 7. Inhibitory control in the visual switch task following mood inductions for young and older adults.

A similar mixed factorial ANOVA performed on inhibitory errors, there was no main effect for mood condition, *F(*1.62, 111.52) = 1.28, *p* = .278, *r* = .11, but there was a main effect for age group, F (1, 69) = 6.82, *p* = . 011, *r* = .30. Older adults made more errors than young adults, *t(*0.60) = 1.46, *p* = .011, *r* = .88; see Table 10. The interaction between mood condition and age group approached significance, *F(*1.62, 111.52) = 3.20, *p* = .055, *r* = .17. Young adults made a similar number of errors across all mood inductions whereas older adults made fewer errors when in a negative mood and positive mood compared to neutral mood (see Figure 8). Overall observed power for visual task analysis ranged from .247 to .782 (*M* = .56).

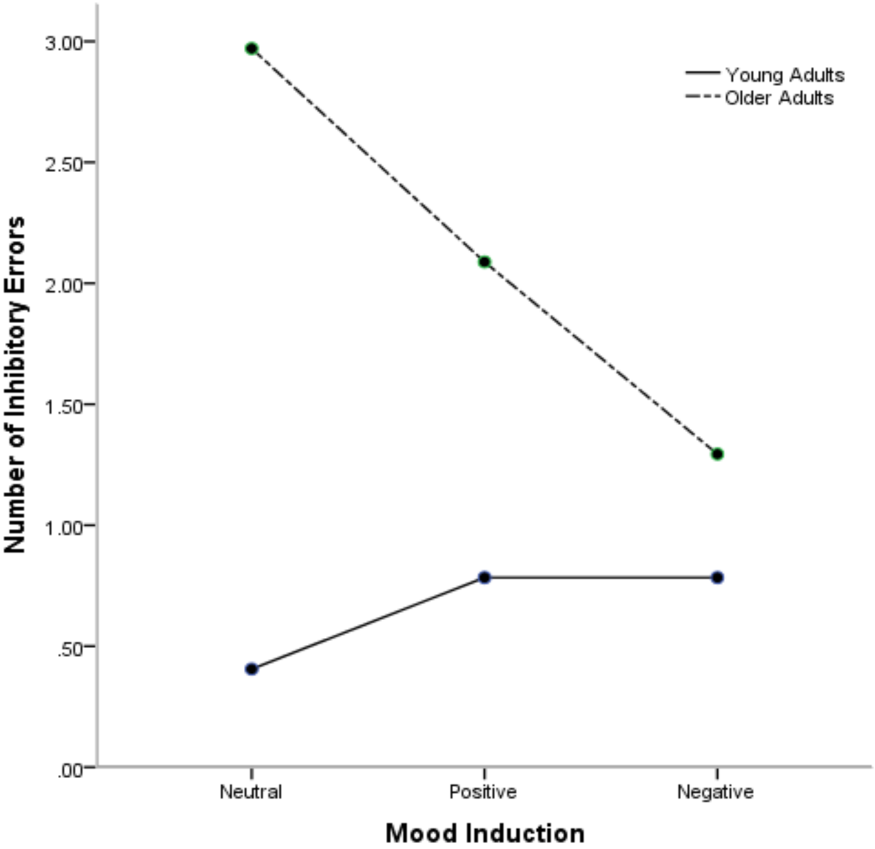

Figure 8. Inhibition errors in the visual switch task following mood inductions for young and older adults.

ANCOVA. Given that working memory and processing speed affect cognitive performance in older adults, these variables were entered as covariates in an ANCOVA. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA was performed with the average reaction time in the reaction time task and the number of errors in the N-back task entered as covariates.

Verbal switch task. A 2 (age group) x 3 (mood condition) mixed factorial ANOVA with the covariates was performed for the inhibitory control, no main effect was found for mood condition, *F(*1.58, 105.63) = 0.70, *p* = .466, *r* = .08, or age group, *F(*1, 67) = 0.35, *p* = .562, *r* = .07. None of the interactions were significant for mood condition and reaction time, *F(*1.58, 105.63) = 0.27, *p* = .708, *r* = .05, mood condition and N-back errors, *F(*1.58, 105.63) = 0.43, *p* = .607, *r* = .06, or mood condition and age group, *F(*1.58, 105.63) = 1.80, *p* = .177, *r* = .13. A similar mixed factorial ANOVA performed on inhibitory errors found no main effect for mood condition, *F(*1.22, 81.73) = 0.07, *p* = .934, *r* = .03, or age group *F(*1, 67) = 0.23, *p* = .630, *r* = .06. No interaction was found between mood condition and reaction time, *F(*1.22, 81.73) = 0.03, *p* = .896, *r* = .02, or mood condition and N-back errors, *F(*1.22, 81.73) = 1.16, *p* = .297, *r* = .118. There was a significant interaction between mood condition and age group, *F(*1.22, 81.73) = 3.93, *p* = .043, *r* = .21; see Figure 9. Young adults made a similar number of errors across mood inductions whereas older adults made fewer errors in a negative and positive mood compared to neutral mood (see Table 11). Overall observed power ranged from .054 to .549 (*M* = .17).

Table 11

Young and Older Adults Average Inhibition Errors for Verbal Switch Task Across Mood Inductions with Standard Errors and Confidence Intervals

Group	Mood	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Young Adults	Neutral	.872*	.616	-.357	2.100
	Positive	1.260*	.500	.262	2.257
	Negative	.949*	.307	.337	1.561
Older Adults	Neutral	2.463*	.644	1.178	3.749
	Positive	1.570*	.523	.527	2.614
	Negative	1.114*	.321	.474	1.755

Note. *Inhibition errors following mood inductions are estimates after taking into account the covariates of N-back task errors = 4.80 and average reaction time = 449.37.

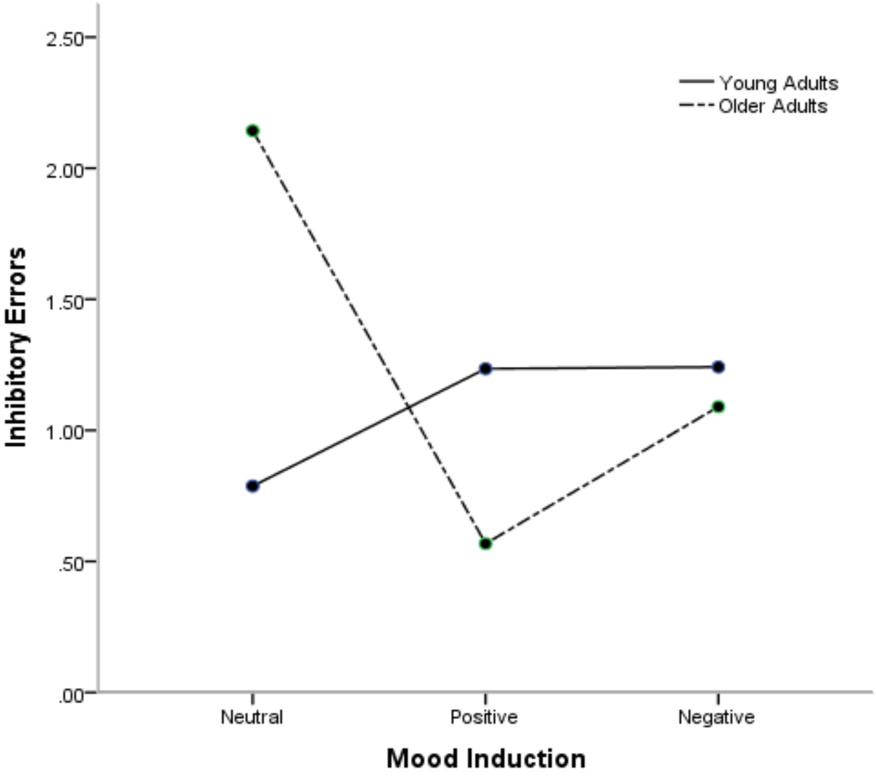

Figure 9. Inhibtion errors in the verbal switch task following mood inductions after controlling for covariates for young and older adults. Inhibition errors following mood inductions are estimates after taking into account the covariates of N-back task errors = 4.80 and average reaction time = 449.37.

*Visual switch task***.** A 2 (age group) x 3 (mood condition) mixed factorial ANOVA with covariates of reaction time and n-back errors for inhibitory control. There was no main effect for mood condition, *F(*1.33, 88.95) = 0.82, *p* = .400, *r* = .10, or age group, *F(*1, 67) = 1.67, *p* = .201, *r* = .16, was found in inhibitory control. No interaction was found between mood condition and reaction time, *F(*1.33, 88.95) = 2.08, *p* = .147, *r* = .15, or mood condition and N-back errors, *F(*1.33, 88.95) = 0.71, *p* = .441, *r* = .088. The interaction between age group and mood condition was significant, *F(*1.33, 88.95) = 3.62, *p* = .049,, *r* = .20; see Figure 10. Both young and older adults had better inhibitory control in a negative mood compared to neutral mood (see Table 12). Older adults also showed better inhibitory control in a positive mood than neutral mood whereas there was no difference for young adults.

Table 12

Young and Older Adults Average Inhibitory Control for Visual Switch Task Across Mood Inductions with Standard Errors and Confidence Intervals

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
	117.683*	78.150	-38.305	273.671
Young Adults	98.692*	67.591	-36.221	233.605
	107.872*	62.844	-17.565	233.309
	400.650*	81.745	237.486	563.814
Older Adults	3.506*	70.701	-137.613	144.625
	65.019*	65.735	-66.189	196.226

Note. *Inhibition control following mood inductions are estimates after taking into account the covariates of N-back task errors = 4.80 and average reaction time = 449.37.

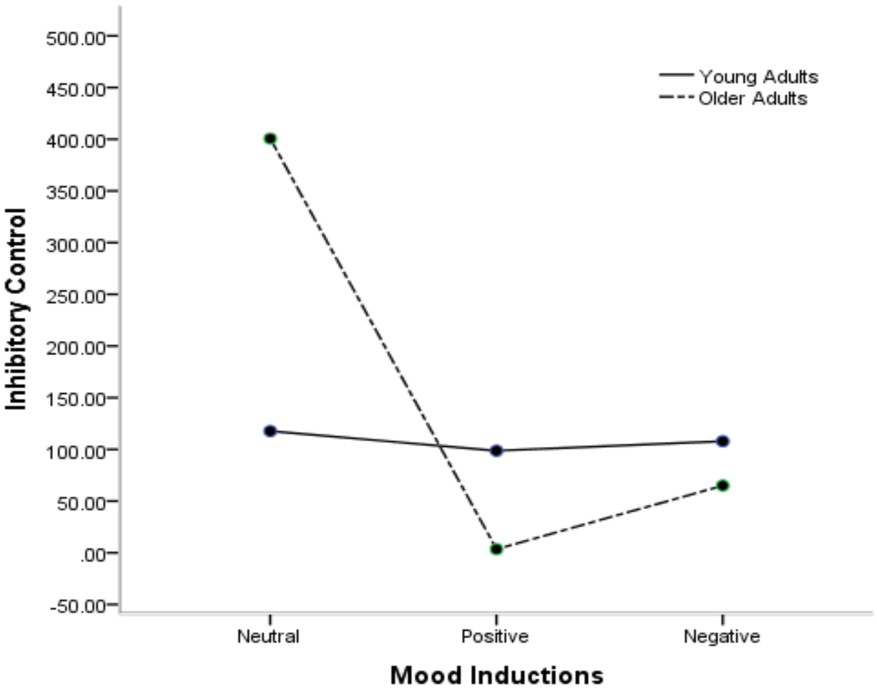

Figure 10. Inhibitory control in the visual switch task following mood inductions after controlling for covariates for young and older adults. Inhibition control following mood inductions are estimates after taking into account the covariates of N-back task errors = 4.80 and average reaction time = 449.37.

A similar mixed factorial ANOVA with covariates was performed on inhibitory errors. The main effect for mood condition approached significance, *F(*1.62, 108.81) = 3.12, *p* = .059, *r* = .17. There was a trend in which participants made fewer errors in a negative mood (*M* = 1.03, *SD* = 0.22) compared to neutral mood (*M* = 1.67, *SD* = 0.43) after covariates were held constant. There was no main effect for age group for inhibitory errors, *F(*1, 67) = 1.631, *p* = .206, *r* = . 15. No interaction was found or mood condition and N-back errors, *F(*1.62, 108.81) = 0.48, *p* = .584, *r* = .066. Interaction between mood condition and reaction time was significant, *F(*1.62, 108.81) = 3.78, *p* = .034, *r* = .18.

Interaction between mood condition and inhibitory errors was not significant, *F(*1.62, 108.81) = 1.68, *p* = .197, *r* = .12. Observed power ranged from .085 to .629 (*M* = .32).

Mood as Facilitator Theory Analyses

Previous studies have not adequately addressed mood as a facilitator theory. The mood as a facilitator theory suggests that positive mood should be associated with greater switching abilities if task interest, enjoyment and motivation levels are high. However, if task interest and motivation is low, participants in a positive mood should have reduced switching performance. The ratings for task interest, enjoyment and motivation were combined into one score (higher scores indicated greater task enjoyment, interest and motivation levels) and participants were separated into two groups using a median split: those who reported low scores after the positive mood induction (37 people who scored less than or equal to 29) and those who scored high after the positive mood induction (34 people who scored greater than 29). T-tests were conducted between the two groups for differences in their switching and inhibition performance (switch cost, decision errors, switching errors, inhibitory control, and inhibitory errors). The two groups showed no difference in the verbal switching task's switch cost, *t(*69) = 0.24, *p* = .81, *r* = .03, decision errors, *t(*69) = 1.44, *p* = .16, *r* = .17, or switching errors, *t(*69) = 1.01, *p* = .31, *r* = .12, while in a positive mood. There was a significant difference in the visual switching task's switch cost, *t(*69) = 2.33, *p* = .023, *r* = .27. Specifically, participants in the low motivation group showed a higher switch cost (M = 319.52, *SD* = 300.95) than participants in the high motivation group (M = 175.21, *SD* =208.68). A significant difference was found between motivation groups and the number of switching type errors, *t(*37.72) = 2.40, *p* = .022, *r* = .36. Participants in the low motivation group made more switching type errors (M = 1.86, *SD* = 3.72) than participants in the high motivation group (M = 0.38, *SD* = 0.55). There was no difference in decision type errors, *t(*40.54) = 1.26, *p* = .215, *r* = .19, following positive mood.

Chapter IV

Discussion

This study aimed to examine the effect of mood changes on shifting abilities in young and older adults. Several of the current theories proposed to explain the effect of mood on cognitive processing were also investigated. Contrary to our expectations that young adults would show different mood effects on their shifting abilities in a forced switching task, young adults generally did not differ in their switching performance across mood inductions. There were no differences in young adults' switch cost between neutral mood and positive mood and between neutral mood and negative mood for the verbal switch task. In the visual switch task, there was no difference in switch costs but young adults made more switch errors following a positive mood compared to neutral mood in the visual switch task. There was no difference in switch errors between negative and neutral mood. These results are consistent with many previous studies demonstrating positive mood is associated with greater switch costs in forced switching tasks (Chu & Abeare, 2011; Phillips, Bull et al., 2002; Dreisbach & Goschke, 2004). This study adds to the literature by using a within subject design with demonstrated changes in mood in a positive direction following a positive mood induction. The results of this study suggest that positive mood reduces set switching abilities among young adults. No difference was found in their ability to inhibit and reduce interference from irrelevant dimensions of the task during switching across different mood inductions. This is inconsistent with past research showing that positive and negative mood did not affect inhibitory control

(Chepenik et al., 2007; Martin & Kerns, 2011; Stafford et al., 2010). Our study results were similar to Larson and colleagues (2013) found that low arousal, negative mood such as feeling sad does not affect inhibition.

To my knowledge, this is the first study to investigate the effects of mood induction on set switching abilities in older adults. I predicted that older adults would either show decreased switching performance when induced in a positive and negative mood compared to a neutral mood because of increased emotional processing load affecting their task performance or they would show no difference in their performance across the different mood inductions due to well developed emotional regulation skills. Contrary to our predictions, older adults showed better switching performance with reduced switch cost and/or fewer switch errors in the visual and verbal switch task while induced in a positive or negative mood compared to a neutral mood. This improved switching performance was robust even after taking into account important variables related to performance in older adults such as working memory and processing speed. Older adults showed better inhibitory control and made fewer inhibition errors in positive and negative moods during the switching paradigm than they did in a neutral mood. Again these findings were still evident even after controlling for the covariates of working memory and processing speed. These findings contrast with Phillips and colleagues' (2002) results showing that older adults demonstrated poorer performance on a planning task when induced in a positive or negative mood compared to neutral mood. However, although both planning and set switching are considered to be executive functioning, planning is more related to the updating and inhibition functions whereas our computerized shifting task is more related to shifting abilities (Miyake et al., 2000). Phillips' study used a between subjects design whereas this study utilized a within subjects design. The greater number of participants and the within subjects design in this study provide a more powerful examination of mood effects.

We propose a few possible explanations for these results. First, there is evidence that older adults are better able to regulate their emotions so that it does not negatively impact their cognitive performance (Scheibe & Blanchard-Fields, 2009). Young adults showed a reduced task performance when asked to engage in regulating emotion while performing a working memory task whereas older adults showed no decline in their performance when asked to regulate their emotion during the task. Older adults in our study may have placed greater focus on the switching task to regulate their mood and therefore, showed better performance in positive and negative moods during the visual switching task. Focusing on the task itself may be an emotional regulation strategy. Older adults may have been trying to repair their negative mood by focusing on the task at hand and maintaining their positive mood by engaging in the task to beat their previous performance.

Another possible reason why older adults performed better in positive and negative mood inductions compared to neutral mood is changes in arousal. Given that older adults showed few differences in their performance between positive and negative mood, mood arousal rather than mood valence changes may be contributing to the performance enhancement. As previous mentioned, the amount of arousal on performance follows an inverted U pattern (Yerkes & Dodson, 1908). The positive and negative mood inductions may have changed older participants' arousal levels to an optimal amount leading to improved task performance. Arousal levels among older adults were examined using the aware-unaware scale on the mood self-report measure. Older adults reported increased arousal following the positive mood (*M* = 1.91, *SD* =

1.38) compared to neutral mood (*M* = 2.59, *SD* = 2.00), *t(*33) = 2.72, *p* = .010, *r* = .43, and compared to negative mood (*M* = 3.29, *SD* = 2.21), *t(*33) = -4.26, *p* < .001, *r* = .60. However, older adults reported lower arousal in negative compared to neutral mood, *t(*33) = -3.08, *p* = .004, *r* = .47. While arousal may have accounted for the improved performance in positive mood, it does not adequately explain the negative mood findings.

Alternatively, our results may be explained by practice effects because participants first performed the set-switching task in a neutral mood before they did the switching task again in positive and negative mood inductions. Research shows that practicing switching between specific tasks reduces the switch cost (Allport et al., 1994, Meiran, 1996). It may be that older adults got better at doing the switching tasks because they had practiced the task. Older adults have specifically shown to benefit from practice by showing greater reduced switch costs and better accuracy than young adults over several sessions of set switching (Cepeda, Kramer, & Sather, 2001; Kramer, Hahn, & Gopher, 1999). Following this line of logic, young adults should show practice effects too. There is some evidence for improved switching cost and reduced inhibitory control in the visual switching task for positive and negative moods compared to neutral moods for young adults. However, performances in young adults were generally not significantly different across mood inductions. It is possible that young adults' attempts at mood regulation following positive and negative mood induction reduced their switching performance and thereby eliminating the practice effect. Consistent with the idea that young adults have difficulty with cognitive task performance while regulating emotions, Scheibe and Blanchard-Fields (2009) found that young adults showed a reduced task performance when asked to engage in regulating emotion while performing a working memory task.

When examining task performance differences between older and young adults while in a neutral mood, majority of the findings from this study are consistent with the literature showing that older adults perform worse than young adults. Generally, older adults took longer than young adults to complete most of the control tasks, consistent with research showing that older adults have slower decision speed (Salthouse, 1995; Uttl & Graf, 1997). Older and young adults showed similar performances on the control tasks of the verbal switch task (deciding on the number of syllables and whether the word is animate or inanimate for each word). Older adults in this study had greater language fluency and vocabulary, which may have given them a slight advantage to overcome their general reaction time disadvantage compared to young adults. When examining the errors, older and young participants were similar in their performance except for the colour task; older participants made more errors when deciding whether the figure was a colour or shades of grey. During the control trials, some of the older adults reported mistakenly thinking that the lighter shades of grey were blue and therefore responded incorrectly to colour in those instances.

When participants engaged in a cued based switching task after the neutral mood induction, which served as a baseline performance, there was no difference between young and older adults for their switch cost but older adults made more errors in the visual switching task. Older adults also showed reduced inhibitory control compared to young adults during the visual switching task. Consistent with our predictions and the literature, older adults showed reduced set switching abilities and inhibitory control in comparison to young adults. Looking at both the switch cost and the errors made are important in examining set switching performance because participants may not show differences in their switch cost but may make more errors because of speed accuracy tradeoffs.

When examining differences between older and young adults across mood inductions, older and young adults performed similarly with regards to their switching and inhibitory control for both switching tasks. There were group differences in the errors made. Interestingly, older adults made more decision type errors and fewer switching type errors than young adults in the visual switch task. Older adults made more inhibitory errors than young adults while doing the visual switching task. The switching and decision type errors have been found to measure two different things. Arbuthnott and Frank (2000) found that errors of failing to switch tasks (switching errors) are related to difficulty switching between tasks whereas errors in selecting the appropriate response (decision errors) are related to task specific process such as task difficulty rather than the switch process. This may explain the difference in performance between older and young adults. Older adults are better at switching following a positive mood than young adults as they made fewer switching errors. But older adults struggled to choose the right response in the specific task. Recall that older adults in our study made more errors in the control colour task than young adults, therefore, they may be having trouble deciding whether the figure is coloured or shaded during the switching task. The forced switching task in our study requires working memory capacity as participants must remember the instructions for the two different tasks (Task A and Task B), when they have to switch based on where the stimulus was presented on the screen (top vs. bottom half of the screen) and the two different responses necessary for each task (e.g. colour/shades of grey and triangle/square). Task switching has been hypothesized to involve elimination of a no longer relevant task set from working memory and reactivation of current relevant task set (Mayr & Kligel, 2003). Older adults may have been using their working memory capacity to remember when they had to switch tasks leading to better performance in their switching errors. But given their reduced working memory capacity compared to young adults, it may have been harder for older adults to deal with the extra load of choosing the right response for the task set and therefore leading to more decision errors and inhibition errors. Consistent with this hypothesis, there was a positive correlation between N-back errors and decision errors for older adults in the visual switching task after the neutral mood induction, $r = .40$, $p = .019$, positive mood induction, $r = .60$, $p < .001$, and negative mood induction, $r = .46$, $p = .006$, suggesting that working memory capacity is related to decision type errors. Similarly, significant correlations were found between inhibition errors in the visual task after neutral mood, $r = .43$, $p = .011$, positive mood, $r = .54$, $p = .001$, and negative mood, $r = .61$, $p < .001$. In contrast, there were no significant correlations between N-back errors and switching type errors in the visual switching task for neutral and positive mood inductions; only a correlation was found with negative mood, $r = .55$, $p = .001$.

Among young adults, there were no significant correlations between N-back errors and switch, decision and inhibition errors for verbal and visual switching task across mood inductions. This suggests that older adults' working memory capacity may be related to their accuracy levels during set switching tasks whereas working memory capacity does not appear to be related to young adults' set switching performance. Working memory has been shown to be an important factor when determining the magnitude of age related differences in set switching (Kramer, Hahn, & Gopher, 1999) such as when working memory load was increased in a set-switching task, older adults had greater switch costs than young adults whereas older and young adults performed similarly when there was less working memory demand.

Previous studies investigating the effect of mood on executive functioning have rarely examined the positive mood as facilitator theory. The current results provide supporting evidence for this theory. Participants in this study were split into two groups: individuals with high task enjoyment, interest and motivation ratings were grouped in the high motivation group and individuals who rated lower task enjoyment, interest and motivation were grouped in the low motivation group, based on median split. Consistent with the theory, following induction of a positive mood participants in the low motivation group showed a greater switch cost and made more switching type errors than participants in the high motivation group during the visual switching task. Examination of switching performance between the low and high motivation groups during neutral and negative moods showed that there was no difference in their switching performance for switch cost and errors made for visual and verbal tasks, indicating that the effect was specific to positive mood.

When examining older adults performances following positive and negative mood inductions, older adults appeared to do better in a positive mood- they had a reduced switch cost and improved inhibitory control in the visual switching task and made less inhibition errors in the verbal switching task. This finding may be explained by the positive mood as a facilitator theory. Older adults rated their mood as more positive than young adults after the positive mood induction. Older adults also rated the set-switching task as more enjoyable, $t(69) = -2.41$, $p = .01$, $r = .27$, interesting, $t(69) = -3.27$, $p = .001$, $r = .37$, and reported being more motivated, $t(69) = -2.10$, $p = .008$, $r = .25$, than young adults after the positive mood induction. Consistent with the positive mood as facilitator theory, positive mood facilitated inhibition performance in older adults because they were more motivated and found the task more enjoyable than young adults. These results suggest that positive mood may act as a facilitator for cognitive performance if motivation and task interest is high.

Lastly, this study investigated whether positive mood and negative mood differentially affected set switching performance based on the type of task used. Research shows that regionally specific, lateralized activation of brain regions relevant to a task is associated with better performance (Gur et al., 1994, 2000; Wendt & Risberg, 1994); meaning that greater activation of the right hemisphere as a result of negative mood will produce better performance on visual tasks that also use the right hemisphere (visual spatial tasks). In contrast, the greater activation of the left hemisphere as a result of positive mood will produce better performance on verbal tasks that also use the left hemisphere. Positive mood has been found to facilitate performance on verbal working memory tasks but reduce performance on visual working memory tasks. Negative mood has been shown to have the opposite performance pattern. However, this effect was not found during this study. When participants were induced in a positive mood, there was no difference in their switching or inhibition performance on the verbal set-switching task compared to their performance in a neutral mood. When participants were induced in a negative mood, they performed better in the visual set-switching task compared to a neutral mood. They showed a reduced switch cost and better inhibitory control under a negative than neutral mood. But this effect was not specific to negative mood because participants in a positive mood also showed reduced switching cost and better inhibitory control in the visual task compared to neutral mood. Furthermore, participants showed better inhibitory control in a positive mood compared to a negative mood. Therefore, the results of this study are not consistent with the idea that a regionally specific, lateralized activation of brain regions relevant to a task is associated with better performance.

Limitations

There are several potential limitations of the present findings. First, there were some limitations in our sample. Our sample of young adults was composed of university students and therefore the results may not generalize to other young adults in the community. But past studies have found that using university students had similar effects to studies using participants from the general population (Baas, De Dreu & Nijstad, 2008). Given that older adults in our study had a fairly high education (with most participants having at least a university bachelor degree), it is uncertain whether our findings generalize to older adults with less education. There may be a difference in the amount or type of mood regulation strategy used by less educated adults. Older adults in this study were individuals willing to volunteer their time for research and therefore may be a subsample of older adults that are not representative of all older adults in the population, a common problem among many behavioral studies in psychology (Rabbitt, Lowe, & Shilling, 2001). Also, the young and older adults may not be comparable groups because there were many differences between them such as English fluency, number of anxiety and depression-like symptoms, stress level, self- reported task motivation and memory performance. Therefore, differences in task performance between young and older adults may be related to these extraneous factors.

There were also some limitations regarding the study procedure. Despite the fact that participants were asked to rate their mood accurately and honestly, there is a risk that participants may comply with reporting changes in mood that they believe the researcher is trying to achieve despite lack of true mood changes. However, there is research demonstrating that that demand effects do not play a central role in mood induction procedures (Westermann et al., 1996; Finegan & Seligman, 1995; Scherrer & Dobson, 2009). This study did not completely randomize the order of mood inductions; participants underwent the neutral mood induction first to provide a baseline. Then participants were randomly assigned to either a negative-positive mood induction order or a positive-negative mood induction order. This creates the possibility of practice effects following the negative and positive mood inductions because participants completed the switching task once before. Future inclusion of a control group in which participants complete the computer task three times under a neutral mood induction can help to examine potential practice effects.

Generally, there were few mood effects for the verbal switching task compared to the visual switching task among all participants. The visual switching task performances had greater observed power generally than the verbal switching task performances, which have made it more likely to find significant results in the visual switching task. However, it may be that the visual and verbal tasks are not completely equivalent. Participants took longer to complete the verbal switching task as indicated by greater total average reaction time (M = 1347. 42, SD = 404.86) compared to the visual switching task (M = 1137.00, SD = 411.74) when performing the switching tasks for the first time following the neutral mood induction, $t(86) = 6.75$, $p < .001$,. Participants took longer to complete the repeated trials, $t(86) = 11.40$, $p < .001$, and the switch trials, $t(86) = 11.08$, $p < .001$, of the verbal switching task compared to the visual switching task. But there was no significant difference in the switching cost between the visual and verbal switching tasks or difference in task accuracy between the two tasks. This suggests that participants took longer to make the right decisions within the verbal tasks than switching between tasks.

It may be that the visual tasks were easier because the stimuli are more perceptually salient and automatically processed (shape and colour) compared to the words used in the verbal tasks; we do not automatically determine the number of syllables or decide whether the word is animate or inanimate when reading words. The greater difficulty level of the verbal task may have led to reduced mood effects (Van Dillen & Koole, 2007). Alternatively, the difference in task performance between the visual and verbal switching may be a laterality issue. Moore and Oaksford (2002) found that mood affected performance on a visual learning task but not on a verbal word association task. Verbal tasks such as processing meaning of words and decoding the number of syllables are associated with left hemisphere activation and the left hemisphere has been suggested to play a larger role in emotional modulation than the right hemisphere. It may be that the activation of the left hemisphere during the verbal switching task facilitates emotional regulation, leading to less mood effects found in the verbal task.

Older adults appeared to have greater difficulty on the colour task compared to young adults. Vision changes related to aging such as macular degeneration, diabetic retinopathy and cataracts changes the sensitivity to colour and contrast perception (Birren & Schaie, 2001; Whiteside, Wallhagen, & Pettengill, 2006). These vision changes may have affected older participants' colour task performance and may explain their poorer performance on the colour control task compared to young adults. During the control trials, some of the older adults reported mistakenly responding coloured to figures in lighter shades of grey. This difficulty in the task set may be magnified during switching because older adults' need to use greater resources to do the colour task during the visual switching task in comparison to young adults, thereby affecting their switching performance. Research has found that perceptual processing age-related deficits become more evident when the computational load reaches a certain level of complexity (Faubert, 2002)

Future Directions

This is the first study to examine the role of mood in set switching between older and young adults and therefore, further studies are needed to replicate our findings. Given that mood regulation differences have been found between older and young adults, it would be helpful for future studies to interview participants to find out if they are regulating their mood during switching tasks and the types of strategies they are using to do so. Research on set switching has identified different stages and processes. Mayr and Kligel (2003) suggested two stages in task switching: cue driven retrieval of rules for the task demands that involves loading current task demands from long term memory into working memory and the application of task rules applied once the stimuli is presented. Rubinstein, Meyer and Evans (2001) indicated two processes in switching- the executive control processes and the task response processes. Within the executive control processes, there is the goal shifting stage that keeps track of current and future tasks and rule activation stage that enables rules for selecting current task response and disables rules for selecting prior task response. It would be beneficial to examine how mood changes affect these different stages of set switching, for example whether mood inductions affect the bottom up processes such as proactive interference and negative priming and/or top up processes such as executive functioning aspects (e.g. inhibition, working memory). Our study used an external cue of where the stimulus was presented on the screen to indicate which task to conduct. It would be interesting to see whether participants under mood inductions perform similarly when asked to switch tasks based on an internal cue (such as after every three trials) or to switch tasks on their own voluntarily (Arrington & Logan, 2005).

Summary

The current study results indicate that very subtle influences and changes in an individual's mood, elicited by such activities as watching a brief movie clip, affect cognitive performance differently between young and older adults. Small changes in mood in a negative or positive direction are associated with better shifting and inhibitory abilities in older adults as measured on forced, cued based switching tasks. Young adults showed reduced set shifting abilities while in a positive mood and made more errors when asked to shift between two different visual tasks. Older adults are better able to regulate their emotions than young adults and tend to regulate their emotions across a variety of situations compared to young adults (Knight et al., 2007; Mather & Carstensen, 2005). This constant mood regulation typically exhibited by older adults makes the regulatory process less effortful and takes up fewer resources (Scheibe & Blanchard-Fields, 2009). Despite declining functioning of the frontal lobes, older adults appeared to use life experiences and well developed emotional regulation skills to compensate for losses in executive functioning.

Our study also found evidence that level of motivation reported by participants during a positive mood induction plays a role in the switching cost. Participants in the low motivation group showed greater switch costs and made more switching type errors than participants in the high motivation group when performing a visual switch task. Positive mood was related to improved inhibition performance among participants reporting greater enjoyment for the task and higher motivation to do the switching task.

These results suggest that positive mood acts as a facilitator for cognitive performance when motivation and task interest is high.

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Appendix A

Mood Questionnaire

On this questionnaire, there are word pairs depicting opposite feelings. On each scale, please circle the number that best describes the way you are feeling right now?

1 2 3 4 5 6 7 8 9

Refreshed Tired

1 2 3 4 5 6 7 8 9

Calm Anxious

1 2 3 4 5 6 7 8 9

Alert Unaware

1 2 3 4 5 6 7 8 9

Positive Negative

Appendix B

Computer Task Questionnaire

Please answer the following questions about the computer task you have just completed. There are no right or wrong answers, just answer as accurately and honestly as possible.

1. Was the computer task boring?

1 2 3 4 5 6 7 8 9
Not at all Very much

2. Was the computer task difficult?

1 2 3 4 5 6 7 8 9
Not at all Very much

3. Did you find the computer task interesting?

1 2 3 4 5 6 7 8 9
Not at all Very much

4. Did you enjoy doing the computer task?

1 2 3 4 5 6 7 8 9
Not at all Very much

5. Did you try to do your best on the task?

1 2 3 4 5 6 7 8 9
Not at all Very much

6. Do you think you make lots of mistakes during the task?

1 2 3 4 5 6 7 8 9
Not at all Very much

7. If you did the task again, how much better do you think you would do?

1 2 3 4 5 6 7 8 9
Not at all Very much

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