DEPARTIMENT OF PSYCHOLOGY

SOCIAL COGNITION AND NORMAL AGING: BEHAVIORAL AND ELECTROPHYSIOLOGICAL SUBSTRATES

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Περίληψη στα ελληνικά

Αρκετές έρευνες στον τομέα της φυσιολογικής γήρανσης και της επίδρασής της στην κοινωνική νόηση σημειώνουν ως πιθανή αιτία της μείωσης των δεξιοτήτων αυτών την ούτω καλούμενη «υπόθεση του μετωπιαίου λοβού». Σύμφωνα με την προειρημένη υπόθεση η επίδραση της φυσιολογικής γήρανσης στις γνωστικές δεξιότητες γενικότερα και στην κοινωνική νόηση ειδκότερα οφείλεται σε δυσλειτουργίες που εντοπίζονται στον μετωπιαίο λοβό, περιοχή που θεωρείται ότι επηρεάζεται ενωρίτερα από άλλες κατά τη φυσιολογική γήρανση. Ταυτόχρονα όμως, αρκετά συχνά, παρουσιάζεται το φαινόμενο μια ομάδα ηλικιωμένων να αποδίδει ικανοποιητικά σε διάφορα γνωστικά έργα. Το φαινόμενο αυτό εξηγείται μέσω της «υπόθεσης της αναπλήρωσης», σύμφωνα με την οποία, ο λόγος που συγκεκριμένα άτομα διατηρούν αυξημένες ικανότητες κατά την εκτέλεση διάφορων γνωστικών έργων είναι η ενεργοποίηση διαφορετικών περιοχών του εγκεφάλου και συνεπώς η ενεργοποίηση εναλλακτικών τρόπων εκτέλεσης των έργων αυτών. Οι θεωρίες αυτές σχετίζονται και με τις έρευνες που διεξάγονται στο πλαίσιο της θεωρίας του γνωστικού αποθέματος. Σε ό,τι αφορά την κοινωνική νόηση, εκτός των πιο πάνω υποθέσεων, έχει καταγραφεί σε αρκετές έρευνες το φαινόμενο οι γηραιότεροι ενήλικες να μην παρουσιάζουν δυσκολίες στην αναγνώριση θετικά φορτισμένων συναισθηματικών εκφράσεων, ενώ παρουσιάζονται δυσκολίες στην αναγνώριση των αρνητικών συναισθηματικών εκφράσεων, κάτι που ονομάζεται συνήθως «φαινόμενο της θετικότητας» κατά τη φυσιολογική γήρανση. Αυτή η παρατήρηση συνδέεται συχνά με μηχανισμούς κινήτρων που επηρεάζουν την προσοχή με τρόπο που μεταφέρεται στα θετικά συναισθήματα, δημιουργώντας έτσι έναν μηχανισμό προσαρμογής.

Σκοπός αυτής της μελέτης ήταν να ξεκινήσει ένα συστηματικό ερευνητικό πρόγραμμα για να γεφυρώσει το ερευνητικό χάσμα μεταξύ συμπεριφορικών και ηλεκτροφυσιολογικών συνήσταμένων της κοινωνικής νόησης στη φυσιολογική γήρανση μέσω της διερεύνησης των ηλεκτροφυσιολογικών συνησταμένων της κοινωνικής νόησης σε νεαρούς ενήλικες και φυσιολογικά γηράσκοντες ενήλικες πάνω των 65 ετών.

Για τους σκοπούς αυτής της μελέτης, δυο ομάδες συμμετεχόντων, 28 γηραιότεροι ενήλικες και 27 νεότεροι ενήλικες με σταθμισμένα δημογραφικά χαρακτηριστικά στο φύλο και τα χρόνια εκπαίδευσης, εξετάστηκαν σε μια σειρά απο νευρογνωστικές δοκιμασίες και δοκιμασίες κοινωνικής νόησης, όπως και σε δύο πειραματικά έργα, ένα έργο αναγνώρισης συναισθηματικής έκφρασης στο πρόσωπο, και ένα έργο διάκρισης χιούμορ, με ταυτόχρονες ηλεκτροφυσιολογικές μετρήσεις. Διενεργήθηκαν τέσσερα διαφορετικά πειράματα για να εξεταστούν οι βασικές υποθέσεις της έρευνας.

Στο πείραμα 1 εξετάστηκαν οι διαφορές μεταξύ των ηλικιακών ομάδων σε έργα που μετρούν νευρογνωστικές λειτουργείες όπως εκτελεστικές λειτουργίες, εργαζόμενη μνήμη και γλωσσικές δεξιότητες αλλά και έργα κοινωνικής νόησης, και δυο πειραματικούς σχεδιασμούς - αναγνώρισης συναισθημάτων και κοινωνικής ερμηνείας/ αντίληψης του χιούμορ. Οι γηραιότεροι συμμετέχοντες είχαν χαμηλότερη επίδοση στις εκτελεστικές λειτουργίες, εργαζόμενη μνήμη και έργα αναγνώρισης συναισθημάτων, αλλά είχαν παρόμοια επίδοση σε γλωσσικά έργα και στις αστείες γελειογραφίες.

Στο πείραμα 2 οι ηλικιακές ομάδες εξετάστηκαν σε ένα πειραματικό σχεδιασμό αναγνώρισης συναισθηματικών εκφράσεων σε φωτογραφίες μέσω της μέτρησης του N170 προκλητού δυναμικού. Όλοι οι συμμετέχοντες είχαν σημαντικά ψηλότερα πλάτη ταλάντωσης στο N170 σε οπίσθιες τοποθεσίες ηλεκτροδίων στις μη χαρούμενες φωτογραφίες σε σύγκριση με τις χαρούμενες φωτογραφίες, αλλά στις μη χαρούμενες φωτογραφίες η ακρίβεια ήταν χαμηλότερη και οι διαφορες στο πλάτος ταλάντωσης στις οπίσθιες περιοχες ήταν μεγαλύτερες για τους γηραιότερους συμμετέχοντες από οτι στους νέους. Οι γηραιότεροι συμμετέχοντες είχαν επίσης ψηλότερα πλάτη ταλάντωσης στο χρονικό παράθυρο 150-200msec από οτι οι νέοι, κάτι που υποδηλώνει διαδικασίες αναπλήρωσης.

Στο πείραμα 3 οι ηλικιακές ομάδες εξετάστηκαν σε ένα πειραματικό σχεδιασμό διάκρισης χιούμορ, όπου έγινε ανάλυση ζώνης ηλεκτρικών κυμάτων. Σε σχέση με τους νέους,οι γηραιότεροι συμμετέχοντες είχαν σημαντικά χαμηλότερη ακρίβεια και υψηλότερες συχνότητες στη ζώνη κυμάτων δέλτα σε κεντροαριστερές τοποθεσίες ηλεκτροδίων μόνο στα μή αστεία ερεθίσματα. Η ενεργοποίηση στη δέλτα συχνότητα ήταν επίσης σημαντικά υψηλότερη σε οπίσθιες δεξιές τοποθεσίες ηλεκτροδίων για τους γηραιότερους ενήλικες από οτι για τους νέους,και αυτή η ομαδοποίηση των τοποθεσιών ηλεκτροδίων επιβεβαιώθηκε με ανάλυση παραγόντων.

Στο πείραμα 4 έγινε μια σύνθεση των ευρημάτων από τα προηγούμενα τρία πειράματα. Τα αποτελέσματα έδειξαν ότι η επίδοση στην κοινωνική νόηση είχε σημαντική συσχέτιση με την επίδοση στις εκτελεστικές λειτουργίες. Επιπλέον, το φαινόμενο της θετικότητας στην επεξεργασία συναισθηματικών ερεθισμάτων σχετιζόταν με χαμηλότερη πολυπλοκότητα του έργου (δυσδιάστατες φωτογραφίες ή δυναμικά βίντεο) και η επίδοση στο έργο διάκρισης τουχιούμορ σχετιζόταν περισσότερο με την επίδοση στις εκτελεστικές λειτουργίες παρά με την επίδοση στις γλωσσικές λειτουργίες.

Η παρούσα μελέτη γεφύρωσε το κενό στην έρευνα μεταξύ των συμπεριφορικών και ηλεκτροφυσιολογικών συνησταμένων της κοινωνικής νόησης στη φυσιολογική γήρανση και σύνδεσε με τις βασικές υποθέσεις για τη γήρανση του εγκεφάλου. Εκτός απο τη βαθύτερη κατανόηση του ζητήματος, τα αποτελέσματα αυτής της μελέτης σκιαγραφούν την πορεία για μελλοντικές μελέτες σε αυτόν τον τομέα. Οι θεωρητικές υποθέσεις για τη γήρανση του εγκεφάλου έχουν εν μέρει επιβεβαιωθεί από αυτή την μελέτη, ειδικά η υπόθεση του Μετωπιαίου Λοβού, η υπόθεση της αναπλήρωσης και η υπόθεση δυσλειτουργίας των ανασταλτικών εκτελεστικών λειτουργιών. Πέραν αυτού, η συγκεκριμένη μελέτη προσφέρει μια διαφορετική και απλούστερη εξήγηση του πλεονεκτήματος στην επεξεργασία θετικών συναισθηματικών εκφράσεων στη γήρανση, συνδέοντάς το με την αναπτυξιακή εδραίωση της αντίληψης θετικών συναισθηματικών εκφράσεων. Τέλος, αυτή η μελέτη παρέχει νέες γνώσεις για τη σύνδεση μεταξύ κοινωνικής νόησης και γνωστικών δεξιοτήτων στην γήρανση.

Abstract

This dissertation was informed by three prominent theoretical frameworks relevant to brain aging, cognitive aging and Social Cognition (SC). Existing literature has demonstrated that the effects of normal aging on SC could be explained by the “frontal lobe decline hypothesis”, a notion which states that the impact of biological aging can be initially detected in functions modulated by the frontal lobes. This hypothesis was combined with the “compensation hypothesis”, which refers to the brain’s ability to compensate and perform well during cognitive tasks by activating different brain parts, a very common observation in aging. Complementary to the above, previous research has identified a “positivity effect”, where normal aging adults do not show a decline in perceiving positive emotions, while this decline is observed when facial expressions are negative, a phenomenon attributed to an attentional bias on positive stimuli related to motivational mechanisms.

The principal aim of the study was to begin a systematic research program in order to bridge the research gap between behavioral and electrophysiological components of SC in normal aging, by investigating the electrophysiological correlates of SC in young adults and in normal aging adults over 65 years of age.

Two groups of participants, 28 older adults and 27 younger adults matched in gender and education level, were tested on a series of neurocognitive and SC tasks. Additionally, they completed two experimental tasks, facial expression recognition and a humor discrimination task, while simultaneously being measured by EEG. Four different experiments were conducted in order to test the major research hypotheses.

Experiment 1 tested the differences between groups in behavioral measures of neurocognitive functions namely executive functioning, working memory and language abilities as well as SC, emotion recognition tests and social inference/humor perception. Older participants had significantly lower performance in Executive Functions (EF), working memory and emotion recognition tasks, but could perform equally in language and humor perception tasks in images that contained a funny element.

Experiment 2 tested an emotion recognition in still faces experimental paradigm and the N170 ERP component in the two age groups. All participants had significantly higher N170 amplitudes in posterior electrode sites in all-but-joyful items, but all-but-joyful faces yielded as well lower accuracy and bigger differences in some sites for older participants. Older participants also had higher amplitudes in frontal electrode sites in the 150-200 msec time window, indicating compensational processing.

Experiment 3 tested a humor discrimination experimental paradigm with a time frequency analysis. Older participants had significantly lower accuracy and significantly higher delta band activation in frontocentral electrode sites only in non-funny items. Delta band activation was also significantly higher in right posterior electrode sites for older adults, and these distinct electrode site groups were also verified by a factor analysis.

Experiment 4 integrated the findings from the previous three experiments. Results showed that SC performance was mostly related to executive functioning performance. Furthermore, the positivity effect in emotion processing was related to the complexity of the task and that the humor discrimination paradigm was more related to executive functioning performance than language performance.

This study attempted to bridge the research gap between behavioral and electrophysiological components of SC in normal aging and connect them to the basic hypotheses in brain aging. In addition to deepening our understanding on the subject, results from this study pave the way for further studies in this area. Theoretical hypotheses on brain aging have been partially verified by this study, specifically the frontal lobe hypothesis, compensation hypothesis and lack of inhibition hypothesis. Moreover, this study offers a different, and simpler, explanation of the advantage of processing positive facial expressions for the elderly, relating it to the developmental establishment of positive expressions processing. Finally, the study provides information on the association between SC and cognitive abilities in adulthood.

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Chapter 1:

Literature Review

This chapter begins with a literature review on Social Cognition (SC), neurocognitive functions and brain aging. It then proceeds to introduce the reader to the four experiments and associated research hypotheses.

What is Social Cognition?

Social Cognition (SC) consists of a set of primate or human-specific skills that are essential for social interactions. SC abilities emerge very early in childhood and continue to develop throughout adulthood (Adolphs, 2001; Frith & Frith, 2007). While SC research has been gaining ground in the past 15 years, a number of questions are still unanswered. Additionally, despite the proliferation of neuropsychological research in the area of cognitive aging, research in the area of SC and aging is not systematic and is largely inconclusive. This is surprising considering the impact of SC on quality of life (see Metaxas, 2015). The present study is an effort to remedy some of the gaps in the existing literature. Its aim is to initiate a systematic research program that can bridge the research gap between behavioral and electrophysiological components of SC in normal aging.

Emotion recognition, the ability to process information originating from different channels, such as facial expression, voice, prosody and linguistic context, and the ability to interpret or infer other people’s mental states, thoughts and feelings (Theory of Mind, also known as ToM or mentalizing ability) are considered key aspects of SC (Davidson, Scherer, & Goldsmith, 2009; Frith & Frith, 2007). SC has received a considerable attention in the clinical literature over the past few years and has been linked to impaired functionality in a number of neurological and psychiatric disorders (autism spectrum disorders, schizophrenia, Parkinson’s disease (PD), and various forms of dementia including Alzheimer’s disease (Bertrand et al., 2008; Kurtz, 2011; Lough, Gregory, & Hodges, 2001; Saltzman, Strauss, Hunter, & Archibald, 2000). Impairment in SC significantly interferes with social integration and quality of life in the aforementioned clinical populations.

SC combines emotional recognition (being able to recognize emotional responses) with elements from Theory of Mind (being able to draw conclusions about other people’s mental states), providing a tool that can facilitate social cuing and interaction. Penn et al (2008) state that SC research shares four common features. The first feature is the “mentalism” that stems from SC, i.e. the prior knowledge stored in schemata that indicates social attitudes or metacognitive experiences. A second feature of SC is that it is process-oriented. Measurements and experimental settings have to be well defined if they want to provide internal validity. Third, SC is a discipline characterized by interdisciplinary approaches. SC lies at the intersection of social psychology, cognitive psychology, developmental psychology, clinical psychology and neuroscience. Finally, SC researchers are concerned with real-world applications. Research in SC should ensure highest ecological validity and be applicable to clinical or real-life settings (Penn, Sanna, & Roberts, 2008).

How does the literature define a SC process? What functions are necessary for complex social situations to be processed? First, social "data" have to be received and identified. Functions involved in this process can be grouped into two interrelated categories: a. emotion recognition and other non-verbal social cuing, and b. language-related social cuing recognition, such as the subtle use of language in sarcasm and humor, otherwise known as language pragmatics. The existing research on emotion recognition is vast, primarily in the developmental literature. The first signs of emotion recognition can be observed the first time an infant recognizes a smile and its mirroring. The smile, a sign of security and growth for an infant, plays an important role in its development (Strathearn, Li, Fonagy, & Read, 2009). As the human grows older and the brain undergoes morphological and functional changes, the ability to recognize a smile is maintained. Studies have demonstrated that the ability to recognize positive emotional expressions remains intact through older adulthood (see below). This phenomenon is consistent with one of Vygotsky's (1978) central tenets: that what is built early in development decays last.

Another explanation, the 'positivity hypothesis', proposes motivational reasons for this cognitive filtering or so-called "cognitive bias" towards positive emotions. The "positivity hypothesis" in aging is believed to be a coping mechanism that allows us to perceive emotional expressions as more positive than they actually are (see more on this below in the SC and aging section). The ability to interpret facial expressions is associated with community functioning and social skills. Two longitudinal studies found evidence that emotion perception was predictive of functional outcome in later stages of life (for a review, see Couture, Penn, & Roberts, 2006).

Receiving and identifying social signals is one basic function of SC. But how these signals are processed involves other abilities that fall within the SC spectrum. Social inferencing is a basic ability developed early in life to make inferences by observing the behavior of others (Frith & Frith, 2007). In cognitive development, SC reaches a point where the developing human being can use social signals to deliberately influence mental states in others (Frith & Frith, 2007). In order for this to happen, one must be able to understand that while one person is experiencing one mental state, another person may be experiencing another. Once this is established, certain behavioral results may be observed, such as the ability to lie, i.e. to pretend you are in a certain mental state in order to influence the mental state of others. This milestone in cognitive development enables humans to receive information in structured social situations like formal education (Frith & Frith, 2007). In the literature, this is often called Theory of Mind, which falls under the umbrella of SC. Neurodevelopmental conditions like autism spectrum disorders cause significant disruption of this social-cognitive ability, resulting in associated communication, language, and cognitive decline (Davidson et al., 2009; Ecker et al., 2012; Williams, Whiten, Suddendorf, & Perrett, 2001). In cases of autism, "the mirror neuron system" (Williams, Whiten, Suddendorf, & Perrett, 2001)—a specific system of neurons located on the frontal lobe—is believed to be impaired (Ecker et al., 2012; Lombardo et al., 2010). When damage to this system occurs, an imitative disturbance disrupts social inferencing. This condition is characterized by a serious decline in social abilities which in turn can lead to a cascade of developmental impairments known as the clinical syndrome of autism (Williams, Whiten, Suddendorf, & Perrett, 2001).

One important area of language associated with SC and the social use of language is pragmatics. By age three, children learn to incorporate contextual and social cues and alter their language/communication code based on their needs of other communicators. This skill continues to develop during the school years and reaches mastery by the end of adolescence. Pragmatics include both verbal and non-verbal communication abilities like indirect language, social cueing, and communication repair strategies. Language pragmatics includes the ability to understand ambiguous messages, emotional states, or to use and/or to interpret humor appropriately. Not all humor has a "mentalizing" component, meaning an extraction of meaning within words or other stimuli (Forabosco, 2008), but for the purposes of this experiment, only such instances of humor will be examined. The ability to interpret and use language and to be an effective communicator is closely connected to SC abilities, although it isn't always considered a part of SC theoretically due to the distinct brain circuits involved in language processing (Frith & Frith, 2012).

SC is a theoretical concept that describes a set of cognitive abilities used in social interaction. The relationship between neurocognitive and psychological functions and SC is critical for the present study in so far as it aims to explore the relationship between neuropsychological changes associated with normal aging and SC.

SC and neurocognitive functions

Contemporary research reveals that SC depends on a set of cognitive-linguistic skills (Fiske & Taylor, 2013), including executive functioning, working memory, speed of processing, language (i.e. comprehension of abstract language, such as metaphors and humor, and social use of language), interpretation of social situations, and perspective taking (as in Theory of Mind or ToM). Given the complexity of functions involved in SC abilities, declines in this area have been linked to a number of psychological and neurological disorders. As a result, SC is gaining ground in applied psychological practice because it can contribute to the early detection, diagnosis and subsequent treatment of neurobehavioral disorders.

SC is related to executive functioning (EF), a multidimensional construct. The literature suggests that executive functioning can be conceptualized as having four components: volition, planning, purposeful action and effective performance. All are necessary for appropriate, socially responsible and effectively self-interested adult conduct (Constantinidou, Wertheimer, Tsanadis, Evans, & Paul, 2012; Lezak, Howieson, & Loring, 2004). EF impairment is usually attributed to damage to one of the primary frontal cortical-subcortical networks (Lezak et al., 2004; Stuss, 2011). Impairment could result in failing to inhibit emotions and needs in order to effectively apply social inferencing, social signaling and other SC abilities.

Social inferencing is also affected by subcortical pathways through the amygdala and limbic system, which are important neural pathways for the processing of emotional stimuli and for emotion recognition (Le Doux, 2000). Emotion recognition is an important component of complex social inferencing and is relevant to humor perception (Wild, Rodden, Grodd, & Ruch, 2003). It is inevitably mediated by EF in its everyday use through the coordination of complex language processing, social inferencing, such as intention inferencing, and emotional processing.

Apart from executive functioning, SC is also closely associated with language perception and language abstraction. Language use that conveys social information is not perceived effectively by clinical populations with significant impairments in SC, including dementia, acquired brain injury, autism and schizophrenia. This explains why socially sophisticated language use that involves metaphor, sarcasm or humor is generally deficient in patients with these conditions (Covington et al., 2005).

Humor perception is thought to be based on a resolution of a cognitive ambiguity or the detection of an incongruity (Attardo, 1997; Feng, Chan, & Chen, 2014) proposed a three-stage model where the humorous element is identified after the incongruity is discovered. More specifically, the three-stage model suggests that there is an “incongruity” phase where the brain is searching for alternate language meanings. This phase is followed by a “resolution” phase where the meanings are encountered (Attardo, 1997), a function that is supported by a number of electrophysiological studies (Vaid, Hull, Heredia, Gerkens, & Martinez, 2003). The neural underpinnings of this mechanism have been examined in some studies and indicate that the reward system of the brain (flowing from the amygdala to the cortex) may be involved in ambiguity resolution (Wild, Rodden, Grodd, & Ruch, 2003). However, humor processing is mainly linked to the temporoparietal junction bilaterally (Du et al., 2013).

Temporal-electrophysiological components are also involved in SC. Studies using the EEG method, discussed below, have been investigating components of SC in different experimental procedures and time windows.

Electrophysiological components of SC

As far as electrophysiology is concerned, SC studies have investigated two processes: emotion recognition and social inferencing. The N170 is an electrophysiological component that has been researched extensively during static emotion recognition tasks. The N170 is a negative oscillation that manifests itself in the 140-to-180-msec time window in the posterior superior temporal sulcus region (STS) and is mainly believed to be sensitive to structural aspects of facial stimuli. Some studies suggest that it is also modulated by facial expression processing, which involves neural circuits that are separate from the visual encoding networks activated by SC (Blau et al, 2007). These ERP correlates of emotional face processing in mainly still photos are thought to reflect activity within a neocortical system where emotional processing is generated in a task-dependent fashion for the adaptive, intentional control of behavior (Eimer & Holmes, 2007). In general, facial expressions and emotion decoding are considered to be processed in later time windows, such as the N270–400msec time window, where the decoding of a mental state could occur (Eimer & Holmes, 2002; Sabbagh, Moulson, & Harkness, 2004). The N270 is also reported in other studies even when the N170 does not seem to be modulated by emotional expression (Holmes, Winston, & Eimer, 2005).

Social inferencing is the second component of SC of interest to electrophysiology, particularly the P300. The P300 (positive oscillation around 300 msec) generally appears when stimulus detection engages memory operations (Polich, 2007). This late positive component is sensitive to the amount of attention resources that are engaged during dual-task performance (Polich, 2007), such as in Theory of Mind tasks. Theory of Mind tasks modulate the P300, whereas in non-mental state decoding paradigms and in SC-impaired clinical samples, i.e. patients diagnosed with autism, the P300 is reduced (Sabbagh & Taylor, 2000).

Late language components, such as the N400 or late positivity components, are also associated with language use, particularly with processing metaphor and joke comprehension (Coulson, 2004; Federmeier, 2014). In cases of written joke comprehension (Federmeier, 2014; Wild et al., 2003), or even in cases of comprehending funny drawings (Wang, Kuo, & Chuang, 2017), components that involve incongruity scanning and resolution evoke late components such as the N400 and the P600 (Du et al., 2013; Federmeier, 2014; Feng et al., 2014). These components are said to relate to the detection and resolution phase, or the “Aha!” moment, in humor processing, both verbal and non-verbal. Brain areas that are considered to be most associated with humor perception include the right frontal cortex, the medial ventral prefrontal cortex, and the right and left posterior temporal regions. Frontal and temporal areas are very often reported (Amir, Biederman, Wang, & Xu, 2015) along with the left temporoparietal junction, which is considered to be an area where semantic appreciation takes place (Bekinschtein et al., 2011). As far as the aging brain is concerned, this study supports the idea that biological changes which involve cell loss in the frontal lobes and compensational mechanisms employed by older, especially educated adults, could recalibrate all of these functions. The following section is a review of prominent theories on brain aging that are relevant to the behavioral and electrophysiological aspects of SC explored in the present study.

Normal aging and neuropsychological functions

The most prevalent behavioral observation associated with aging is the slowing of processing speed (Salthouse, 2000). This slowing down of the processing system has been implicated in a number of age-related neurocognitive changes. When engaged in multi-stimulus processing, tasks that require time limits are found to be affected first (Zelazo, Craik, &

Booth, 2004). As a consequence of this slowing down of the system, tasks that require online processing, such as word retrieval, divided attention, working memory, and certain EF tasks (i.e. mental shift and mental flexibility), are negatively affected (Salthouse, 2000).

Neuroimaging study results agree that different and more widespread areas of brain activation are observed in older adults when processing cognitive tasks than in their younger counterparts (Reuter-Lorenz, 2002). This has to do with the brain's capacity to recover loss with activation of other brain areas not dedicated to, but capable of, dealing with the task at hand. Likewise, with attentional processing declines, widespread cell loss impedes the brain's capacity to organize sources around a task consequently it gets help from different areas in order to process effectively (Cabeza, Anderson, Locantore, & McIntosh, 2002). This manifests itself as a lack of inhibitory processing where more stimuli or internal processes are occurring at the same time, resulting in more brain activation, slower processing speed and fatigue (Hasher, Tonex, Lustig, & Zacks, 2001; von Hippel, 2007).

The underlying theoretical hypothesis behind the phenomenon of widely distributed brain activation in older adults is actually a combination of two hypotheses. The first is the "compensation hypothesis". As the brain ages and neurons are lost, older people tend to use different brain areas to process stimuli that can't be processed in the specific brain areas dedicated to those processes (Park & Reuter-Lorenz, 2009). In practice, age-related over-activation is linked to better performance in cognitive tasks among older adults (Cabeza et al., 2002). More specifically, it seems that activation is stronger in the prefrontal region and more bilateral than it is for younger people (Reuter-Lorenz, 2002).

The second complementary hypothesis on brain aging is the "frontal lobe decline hypothesis". Neuroimaging studies suggest that brain atrophy begins in the prefrontal lobe. FMRI studies show more brain activity in younger adults in the right amygdala and hippocampus area as compared to older adults, who show more activity in the right anterior-ventral insula cortex (Fischer et al., 2005). When speaking about normal aging, changes in brain functioning are often grouped under the frontal lobe hypothesis, according to which part of the frontal lobe is affected by normal aging earlier and to a greater degree than other areas of the brain. Frontal lobe degeneration is considered to be the primary cause of the cognitive decline observed in older adults (e.g. Haug et al., 1983). This hypothesis has actually been confirmed through a factor analysis in neuropsychological tests taken by normal aging adults (Mittenberg et al., 1989).

In addition to MRI studies, event-related components are also modulated by the effects of aging. The literature suggests that early sensory components, such as the P1, N1 and P2 components, are not modulated by age, while at the same time studies conclude that deficiencies in inhibitory processes are observed as we age.-Late components like the N400, which is associated with higher language, shows modulation, as evidenced by different activation patterns, even if behavioral performance remains intact (Friedman, 2011). (The literature review on SC, normal aging and electrophysiological components continues in experiments two and three (chapters IV and V).

To explain why education level and other social factors play a role in the delay of cognitive decline, the "cognitive reserve hypothesis" was proposed(Stern, 2009) (Giogkaraki, Michaelides, & Constantinidou, 2013; Metaxas, 2015; Park & Reuter-Lorenz, 2009; Whalley, Deary, Appleton, & Starr, 2004). Cognitive reserve is a theoretical construct that explains why some individuals are able to compensate and delay the expression of clinical symptoms even in the presence of brain pathology. To an extent, the cognitive reserve hypothesis is complementary to the compensation hypothesis, giving a behavioral explanation for why some older adults are protected from the neurobiological effects of brain aging. According to this hypothesis, intelligence, education and occupation are the essential factors leading to higher levels of cognitive reserve (Whalley et al., 2004). Language abilities, and in particular semantic knowledge as measured by receptive vocabulary, are influenced by education but are stable across time and can be used in models aiming to estimate cognitive reserve (Constantinidou, Christodoulou, & Prokopiou, 2012; Giogkaraki, Michaelides, & Constantinidou, 2013; Park & Reuter-Lorenz, 2009). Abilities that are stable across time typically fall within the domain of 'crystallized intelligence' and are maintained throughout the lifespan. The present study will incorporate stable cognitive measures, such as receptive vocabulary as well as speed of processing, executive functioning and memory tasks that are vulnerable to aging, into its neurocognitive assessment battery.

SC in normal aging

The positivity hypothesis, which comes from social psychology, is widely accepted in aging studies. According to this hypothesis, focusing their attention on positive experiences and stimuli is an essential coping mechanism for aging adults. This focus on the positive is thought to help older adults remain positive and optimistic about their lives and is often related to the emotional regulation processes, or the "living as best we can while we're still alive" change in motivational effect (Isaacowitz & Blanchard-Fields, 2012 ; Carstensen, 2006; Blanchard-Fields, 2007; Charles & Carstensen, 2007; Isaacowitz & Blanchard-Fields, 2012; Carstensen & Mikels, 2005).

The aging literature also suggests that healthy aging affects certain aspects of SC. The ability to correctly recognize emotional expressions deteriorates in later life. In some studies, age has no effect on emotion recognition through language, whereas emotional recognition in facial expression and ToM tasks decreases (e.g. Phillips, MacLean & Allen, 2002). Specifically, there is evidence that older adults can recognize some emotions better than others (e.g. Suzuki et al., 2007). It is largely observed that older adults seem to have an increased difficulty in recognizing negative emotions, whereas the same doesn't hold true in the case of positive emotions. When identifying positive emotions, older adults seem to be able to maintain their performance when the difficulty of the task remains low (Pavanin, 2008). This may be explained by the "positivity effect" discussed above. There is also an alternative explanation for the positivity effect that is related to the functional re-organization of the brain as it ages (e.g., Cacioppo et al, 2011). This hypothesis attributes the sensitization of the system to positive expressions to their role in evolution and early development, as discussed above (Vygotsky, 1978).

Concerning Theory of Mind tasks, the research is inconclusive. Some studies report a ToM benefit for older adults (Happé, Winner, & Brownell, 1998), while others support a ToM decline in normal aging adults. (Maylor et al., 2002; Duval et al., 2011). According to study results, the effects of age on cognitive functions situated in the ventromedial region of the prefrontal lobe are not as prominent as the effects on functions situated in the dorsolateral region of the prefrontal lobe. These differences can be roughly divided into SC and neurocognition respectively (e.g. MacPherson et al., 2002). This may reflect an SC system that is intact overall and explain why a gradual and cumulative decline in neurocognition precedes the deterioration of SC. The rift between results showing that there is no SC decline (e.g. Happé, Winner, & Brownell, 1998) and those showing that there is a decline (e.g. Maylor et al., 2002) can be explained with this rough distinction in mind. We must also keep in mind that separating these two areas of cognition in a way that the effect of one area on the other is identified and ruled out is problematic because of their tight interdependence (Perner & Lang, 1999; Moses, 2001; McKinnon & Moscovitch, 2006; German & Hehman, 2005). In a study by Duval et al. (2011), age was a defining factor in second-order cognitive ToM decline (the ability to infer what a person thinks about another person's thoughts) as well as an indirect factor mediated by executive functioning decline in first-order cognitive ToM function (the ability to understand another person's thoughts).

The study on which this thesis is based is the second to be conducted after Metaxas (2015) on SC tasks and aged participants in a Greek-Cypriot population. Metaxas reported that age plays an important role in emotion recognition performance, but that it is mediated by education level. He also reported that education mediates the decline in receptive language abilities. Expanding on the findings of Metaxas' 2015 study, the current study aims to investigate SC in educated adults and to identify its electrophysiological underpinnings.

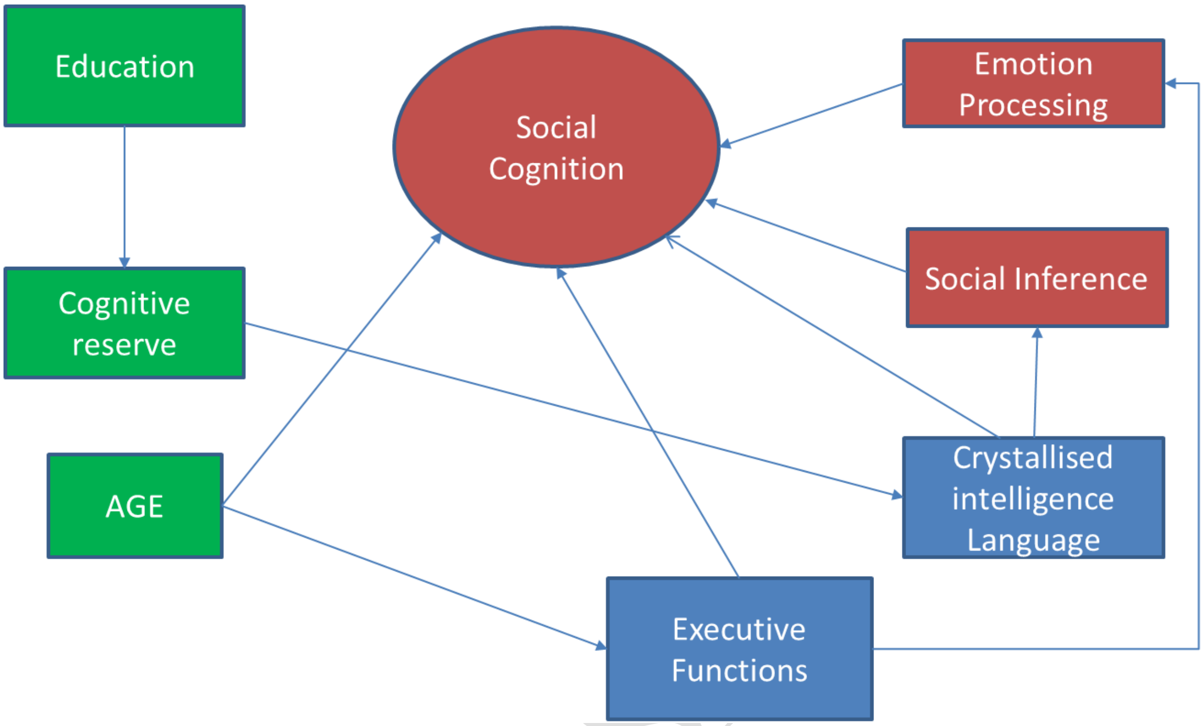
The literature on SC and aging is limited. A few studies attempting to relate different aspects of SC in normal aging to each other point out the interaction between compensational mechanisms and neurocognitive declines through aging. The present study will explore compensatory mechanisms by investigating both behavioral and electrophysiological components of SC in healthy older adults.

Theoretical model proposed in this study

Figure 1 is a graphic display of the theoretical model of SC proposed by this study. The study systematically investigated the relationships outlined in the model. According to the model, SC includes two independent components: Emotion Recognition and Social Inferencing (all in red). SC abilities are influenced by age. Furthermore, EF abilities influence SC in older adults.

The study adopts the theoretical perspective linking levels of education with cognitive compensational mechanisms. Therefore, the sample was chosen so that education was kept stable (all participants had all secondary and some university education, and years of education was matched between age groups). As it was previously mentioned, participants were expected to engage their compensatory mechanisms and therefore perform well on language based measures, indicative of crystallized intelligence. These abilities are expected to influence social cognition through social inference abilities.

Figure 1: Social cognition theoretical model proposed in this study



Purpose of the study

The purpose of this study was twofold: to examine how specific aspects of SC relate to neurocognitive performance, and to investigate electrophysiological correlates related to SC in early and late adulthood. Two matched groups of younger and older adults were given a series of standard neuropsychological tests measuring memory, executive functioning and language, along with a series of SC behavioral paradigms. Additionally, study participants were tested on two experimental electrophysiological tasks measuring SC constructs: social inference (humor discrimination) and emotion recognition (emotional faces). Differences between age groups on behavior-only tasks and experimental electrophysiological tasks were identified at a behavioral and electrophysiological level. The results drawn from the experimental tasks were linked to SC and neuropsychological test scores.

Four experiments were developed in order to test the main hypotheses of this study. Each experiment will be described separately after a methods section. The following were our main hypotheses:

Hypothesis 1*: Behavioral measurements and aging*

1a. As reported by previous studies (Reuter-Lorenz & Cappell, 2008) and by Metaxas (2015), we expected that older participants *would exhibit significantly poorer performance in* *memory and executive functioning as compared to their matched younger counterparts. However, older adults were expected to perform similarly to younger adults in tests assessing language abilities because these tasks are resistant to aging and are part of crystalized intelligence.*

1b. Older participants were expected to show significantly poorer performance on emotion recognition as measured by accuracy and reaction time (Carstensen & Mikels, 2005) in comparison to their younger counterparts. Furthermore, different patterns of performance were expected to emerge between the two age groups in the processing of all-but-joyful emotions as measured by accuracy and reaction time, with older adults being less accurate and requiring more time than their younger counterparts.

1c. It was hypothesized that social inference tasks that are contextually and ecologically based rely heavily on language comprehension and will be stable in aging. It was expected that there would be no differences in humor perception between the two age groups as measured by accuracy and reaction time of funny vs. unfunny items.

Hypothesis 2*: Electrophysiology of facial expression processing in young and older adults*

To determine whether or not differences in age are reflected in electrophysiological measurements, we conducted an experimental "emotional faces" task. For this task, participants were asked to distinguish six basic facial expressions in static pictures. It was *expected that processing positive vs. negative facial expressions would result in significant differences in peak amplitude and latency,* such as the N170 component or later components, for all participants. (Balconi & Pozzoli, 2003). (For a full description of face-related components, see Eimer & Holmes, 2007). Moreover, according to the positivity hypothesis of aging reported in the literature (Mather & Carstensen, 2005), *it was expected that we would find significant differences between age groups during the processing of negative facial expressions as measured by peak amplitude. Older adults would demonstrate a bigger difference in peak amplitude for negative facial expressions than younger adults, but not significantly different than for young adults in positive expressions (as seen in Mather & Casternsen,* 2005).

Hypothesis 3*: Humor discrimination electrophysiological counterparts in young and older adults*

To investigate behavioral and electrophysiological differences in a social inference paradigm, an experimental humor discrimination task was created and conducted. *It was expected that exposure to funny vs. unfunny items would result in electrophysiological differences for both groups as measured by time frequency analysis due to the element of incongruity in funny items* (for the incongruity hypothesis, see Feng et al., 2014). *Furthermore, although it was anticipated that there would be no substantial differences between funny and unfunny items in behavioral measurements between groups,* due to the more ecological nature of the task, **it** *was still expected that there would be significant differences at an electrophysiological level* because compensational mechanisms would ensure that any differences in electrophysiology would not reflect behavioral performance(for example, see (Gunter, Jackson, & Mulder, 1995). Specifically it was expected that older participants would need to employ inhibition mechanisms to a higher degree in order to compensate performance.

Hypothesis 4*: Determining associations between neurocognitive, behavioral and electrophysiological measurements relevant to SC and aging.* Associations between behavioral and electrophysiological measures were made in order to derive conclusions on the link between biological aging, SC and cognitive aging. *It was expected that older adults would perform lower on emotion recognition tasks, especially in those tasks that involved dynamic stimuli, It was also expected that performance in executive functioning and language tests would be related to certain aspects of SC as measured by behavioral (accuracy and reaction time) and electrophysiological indices (peak amplitude, latency and delta frequency) for both groups.*

For older adults, it has been previously reported in the literature that social skills may either not deteriorate due to “social wisdom” (in the case of Theory of Mind, see Moran, 2013) or deteriorate as a result of a decline in certain aspects of EF (von Hippel, 2007). *It was expected that older adults would exhibit a corresponding decline in EF measurements and SC measurements. Language performance as measured by neuropsychological language tests was expected to follow the trend of the SC components under investigation (the proverbs test and humor discrimination electrophysiological measurements), thus not presenting any differences between age groups.*

Statement of Significance

Existing research on SC attempted to examine specific components of SC and the impact of biological aging, albeit with inconclusive findings. Those studies focused on certain aspects of SC using either experimental methodologies or neuroimaging indices. The present study implemented a systematic experimental design and integrated behavioral and electrophysiological measurements to examine hypotheses that entail biological and social/cognitive explanations of adult SC. The results of this study contribute to the development of a comprehensive and integrative model of SC in adulthood and provide guidance for future research in this area.

Chapter II:

General Research Methodology

This chapter describes the overall research methodology, starting with the study participants and progressing to a detailed description of the measures and procedures used in all experiments (list major sections of this review). Methods and procedures unique to the individual experiments are presented in their corresponding chapters.

Participants

Twenty eight older adults (mean age M= 68.46 min 65 max79.15 females, 13 males) were matched with twenty seven young adults (mean age M= 33.68 min 28 max 42.14 females, 13 males) on gender and years of education. Cut-off ages were 65-75 for older adults and 30-40 for young adults. All participants were healthy, with no history of neurological, learning, or significant psychiatric condition requiring hospitalization. Participants were screened for depression, dementia and other age-related neurodegenerative disease. In the next table the results on the screening tool that was used are shown.

Table 1: Descriptives for both groups on the Montreal Cognitive Assessment Test

	N	Min	Max	M	SD
Older	28	24	29	25.89	1.37
Younger	27	23	30	27.1	2.4

Twelve participants were excluded from the second session of the procedure which included the electrophysiological measurements. Six participants were excluded due to left handedness and inability to commit to a second session. Six participants' electrophysiological data were also excluded due to extensive noise in their data. Experiment 2 had 25 older adults and 22 young adults (21 male 26 female) and experiment 3 had 21 older adults and 22 young adults (21 Male 22 female).

Measures

Measures were selected in relation to having a comprehensive cognitive assessment for aging related neurodegeneration. Neurocognitive tasks were translations and adaptations in Greek and Cypriot Greek of different tools (see below). All tools were previously tested and used in other studies at the Centre of Applied Neuroscience (e.g. neurocognitive study of the aging https://clinicaltrials.gov/ct2/show/NCT01481246 (Metaxas, 2015). A SC battery that contained the Cambridge Adult Mindreading (CAM) battery and the reading the test in the eyes from the autism centre https://www.autismresearchcentre.com (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Golan, Sinai-Gavrilov, & Baron-Cohen, 2015) translated and adjusted in Greek, as well as novel tasks that were created and tested and adjusted in a previous study with the collaboration of the author (Metaxas, Shoshilou, & Costantinidou, 2016) was used. The battery measured basic SC aspects which were re-examined in experimental tasks (emotion recognition, higher language functions-social inference). See below for a description of all tests that were given in the order that they were administered.

Standard Neurocognitive functioning measures

1. The Montreal Cognitive Assessment (MoCA)(Nasreddine, 2010) - was designed as a rapid screening instrument for mild cognitive dysfunction. It assesses various cognitive domains: attention and concentration, EF, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation.

2. Logical Memory test-Greek Version (Constantinidou & Ioannou, 2008): tests working memory abilities during story recall. such as chunking and information organization. The variable of interest was the number of the elements from the story recalled is measured immediately after reading as well as a delayed recall.

3. Rey Complex Figure test (Shin, Park, Park, Seol, & Kwon, 2006): Measure for visuospatial constructural ability and visuospatial memory. Variables of interest were accuracy on copying, immediate recall and delayed recall, as well as recognition items.

4. Hopkins Verbal Learning Test (HVLT) (Brandt, 1991): verbal learning test, tests memory abilities of coding and storing information. Initial recall responses are measured as well as short and long delayed recall; correct answers are measured.

5. Digit Symbol (Smith, 1968): tests attention/executive functioning and eye-hand coordination. Number of correct responses and time of completion is measured.

6. Trail making Test A and B (Bowie & Harvey, 2006): executive functioning test, tests visuo-conceptual and visuo-motor tracking, sensitive to mild brain damage. Time to completion is measured.

7. Controlled Oral Word Association Test (COWAT) brief (Ruff, Light, Parker, & Levin, 1996): Verbal fluency test. Measures spontaneous production of words of a specific category or beginning with a designated letter. Number of responses produced is measured.

8. Delayed recall of 1. Logical memory, 2. Rey complex figure, 3. HVLT

9. Depression screening (Geriatric Depression scale GDS) (Yesavage et al., 1982)- This scale was developed as a basic screening measure for depression in older adults. It measures depression according to the DSM criteria for depression diagnosis and focusing on specific symptoms that usually appear in older adults. Number of positive answers is measured.

10. Peabody Picture Vocabulary Test (PPVT-12) (Dunn & Dunn, 1965): Is a measure of receptive vocabulary and is intended to provide a quick estimate of verbal ability. Number of correct responses is measured.

11. Towers of Hanoi - mental task: executive functioning test, tests planning, cognitive inhibition and problem solving abilities, time to completion as well as number of moves are measured

Neurocognitive tests were previously translated and used in studies with Greek Cypriot participants at the Neurocognitive Research Laboratory, Centre of Applied Neuroscience, University of Cyprus (Giogkaraki et al., 2013; Konstantinou et al., 2016)

Social Cognition tests

12. A translated version of the Reading the Mind in the Eyes Test (see http://www.autismresearchcentre.com/arc_tests). This test is designed to measure “mentalizing ability” and is able to distinguish adults with SC impairment conditions such as Asperger syndrome, high functioning autism, or even adults with relevant brain damage (e.g. prefrontal or amygdalectomy, see Baron-Cohen et al,2001 for more details).

13. Recognition of emotions in the moving face / recognition of emotions in the voice (translation and adaptation to Greek of The Cambridge Mindreading (CAM) Face-Voice Battery (Golan, Sinai-Gavrilov, & Baron-Cohen, 2015): This test examines the ability to

recognise emotional states in adults through a variety of emotional states represented either visually in short spots with actors presenting specific emotional states, or acoustically in short spots of actors verbalising sentences that refer to certain emotional states.

14. Speeded movie vignettes: this is a procedure developed by Metaxas (2015), (for an example of a similar test see https://www.autismresearchcentre.com/arc_tests reading the mind in films test) with movie vignettes representing the seven basic emotions in facial expressions to represent an emotional expression in real/natural situations. This test is designed to and has achieved to have a better ecological validity than still photos tests (for validity tests results see (Metaxas, 2015).

15. Proverbs test – this is a procedure developed by Metaxas (2015) where not very common proverbs in the Cypriot Greek dialect were presented while participants need to choose the correct definition out of four choices. It was designed to measure complex language abilities and/or language pragmatics.

All of these tests were translated and adapted to the Greek-Cypriot population previously to this study (Metaxas et al., 2016).

Experimental measures

Behavioral Description

1. Recognition of emotions in faces: Previous research has indicated that there are six so-called "basic" emotions, which are easily recognized by healthy individuals. For the measurement of this ability an existing database of emotion in the face photos was used (Ekman, Friesen, & Hager, 2002). Emotions which participants were asked to recognize are (a) joy (b) sadness (c) anger (d) surprise (e) disgust and (f) fear. Masked face stimuli were presented in a timed manner and followed by a word expressing an emotion (figure 2). Participants were asked to report if the word was correctly reporting the facial expression or not. Forty five photos were presented in a repeated manner interchangeably with all combinations of emotion-words twice so that the task reached 628 trials. Licence was obtained by Ekman (Ekman, Friesen, & Hager, 2002) for the use of these material. The task was piloted with a small number of participants (6 participants) in order to establish that orders were clear and that electrophysiological results yielded a N170 oscillation.

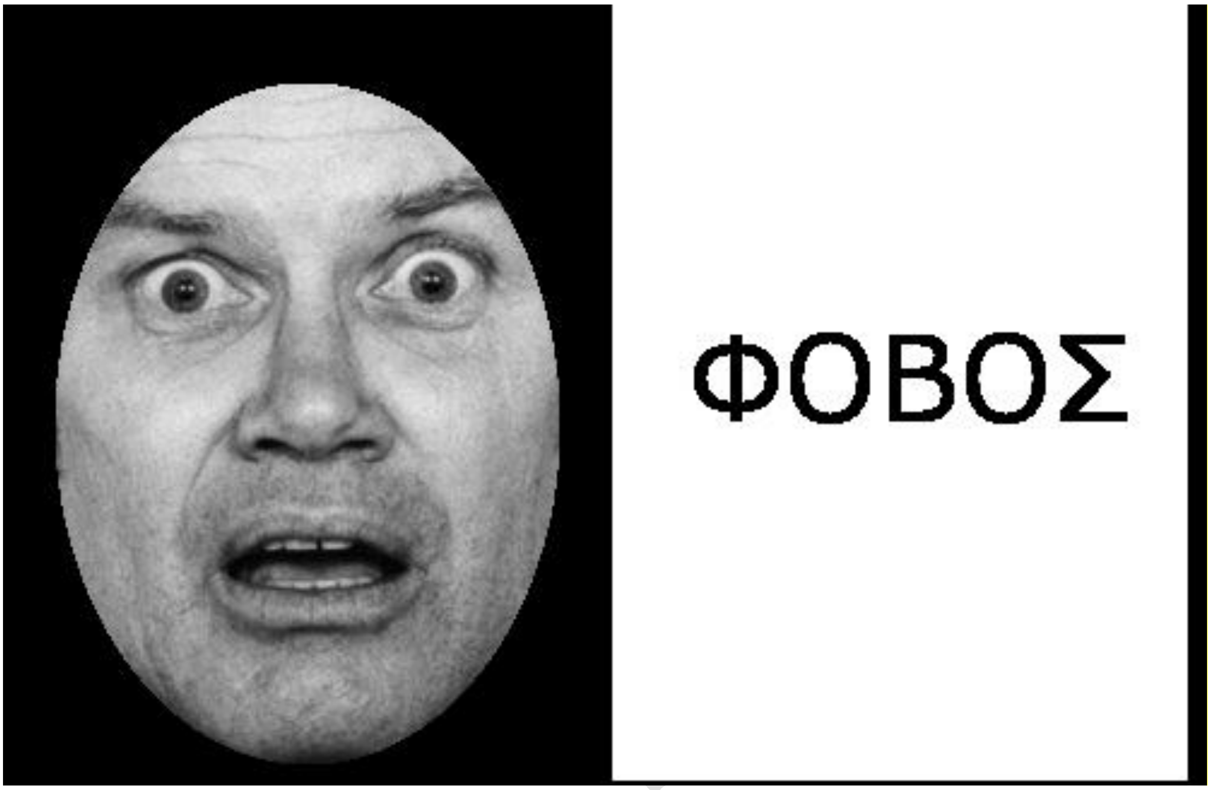


Fig 2. Example of a congruent emotion recognition trial (emotional expression depicting fear and the word fear on the next screen- participants had to press a button to report its correctness)

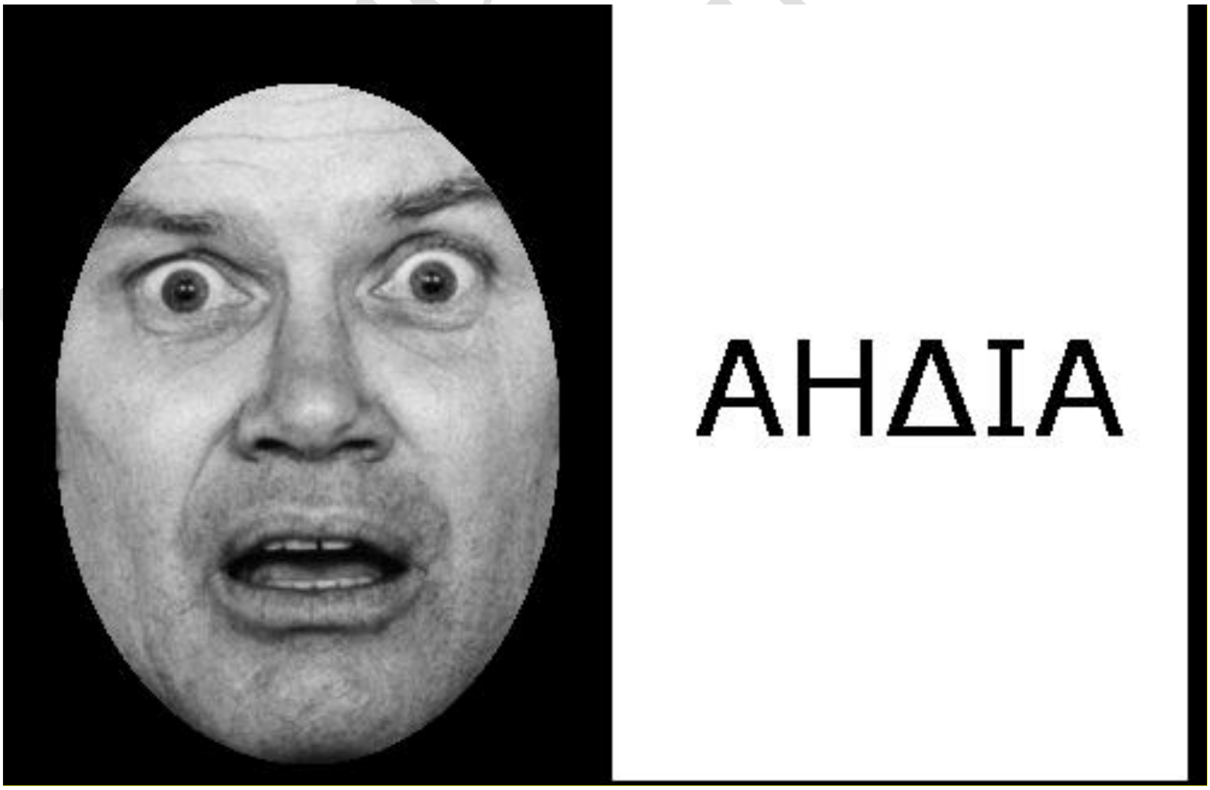


Fig 3. Example of an incongruent emotion recognition trial (emotional expression depicting fear and the word disgust appearing on the next screen): participants had to press a button to report its incorrectness).

2. Humor perception: Cartoons by a well-known cartoonist (ΑΡΚΑΣ http://www.arkas.gr/) were selected from all his publications (licence was obtained by the cartoonist for the use of these images) so that the punchline sentence did not contain more than six words and the cartoon contained two or three sentences in total. A piloting procedure preceded the design of the experiment where forty naive persons of similar age groups to the ones examined (age range 30-70) looked at more than two hundred cartoons containing a funny punch-line or not and judged weather they were funny or not. The question made to participants in the pilot and research measurements was "was this cartoon funny?" orders were given in order for participants to answer weather the task is generally funny and not funny according to their personal taste. The example of jokes that may annoy some but be found funny by others was given, and they were asked to answer if someone in general would find that funny and not them specifically. Seventy items were chosen (36 funny and 34 non funny), that were 70% or more agreed to be funny or non-funny accordingly.

Each cartoon containing one sentence was presented for five seconds. The punchline sentence was then added to the cartoon and participants had three seconds to observe it (figure 4, 5). Cartoons having a humorous social inference as well as neutral cartoons of the same characters were presented and participants were asked after the observation period in a new screen to indicate if the cartoon was funny or not. The behavioural procedure was recorded by EEG. The EEG procedures and measurements are described in the Electrophysiological Measurements section below.

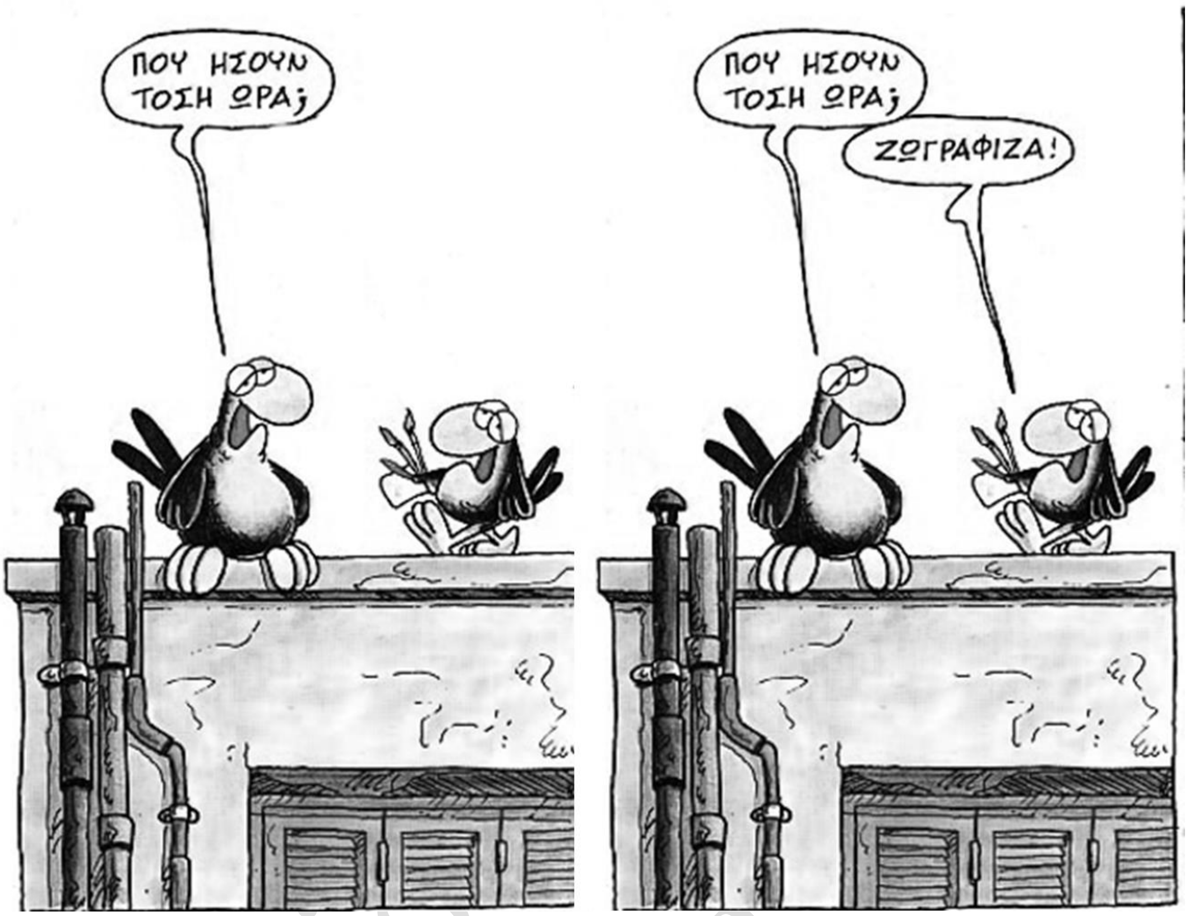


Fig 4: Example of a non-funny cartoon of sparrow father and son series

Dialogues

Image 1: where were you all this time?

Image 2:- where were you all this time?

- I was drawing!

Fig 5. Example of a funny cartoon of the Sparrow father and son series

Dialogues:

image1: -Your cough is much better!

Image2: -Your cough is much better!

–Of course it is! I've been practicing for days!

Experimental Procedure

Participants were recruited with a snowball method from an initial small number of acquaintances of the author. They were tested at the Center for Applied Neuroscience in Central Campus, University of Cyprus. Participants were informed of the procedure (concerning cognitive assessment and EEG measurement) and signed a consent form.

Experimental setting procedures for the ERP: The equipment for the ERP measurements is located in a specially designed laboratory room at the Center of Applied Neuroscience, University of Cyprus. The recommended standard procedures for the placement of the 64 electrode system cap were followed. The participants participated in a brief training session to ensure that they were able to follow the experimental procedures of the study. All stimuli were computerized and special instructions were given in order to minimize noise.

Electrophysiological Measurements

All ERP measurements took place at the Center of Applied Neuroscience in the central campus of the University of Cyprus. The data acquisition equipment was a high-density EEG/ERP recording system, an unshielded 64-channel BIOSEMI Active-Two. The analysis software packages used for processing EEG/ERP data were BESA (https://www.besa.de/) for ERP and signal noise cleaning and averaging, and MATLab routines for the Time Frequency Analysis; Stimuli were presented to the participants through E-prime software (https://www.scienceplus.com/). This software is used to collect behavioral measures (response times, error rates), and can send time triggers to the EEG acquisition software (ActiveView https://www.biosemi.com/software_biosemi_acquisition.htm).

Tasks which were presented required a behavioral response limited to pressing a button on the pc keyboard. Behavioral measures were also collected (reaction time, accuracy). The tasks were expected to elicit visual ERP waveforms based on the type of the stimuli. The effect of attention to specific components was be the main target of the procedure. It was assumed that attention will modulate brain waveforms when emotion recognition and/or social inference most relevant tasks will appear.

1. *Experiment A. Emotion Recognition*

The experimental paradigm targeted visual components. Visual presentations aimed at modulating attention to the task. On the emotion recognition task, participants were needed to identify emotional expressions in faces. The perception of faces is expected to elicit a N170 component. Studies examining the N170 which is described to be the “face” component , point out some modulation of the component according to the facial expression (see Blau, Maurer, Tottenham, & McCandliss, 2007) although there is also evidence that this may be an artefact; Rellecke, Sommer, & Schacht, 2013). It remains a question whether the familiarity of the expression (happy vs other emotional expressions) will modulate this early face perception component as some studies suggest (Eimer & Holmes, 2007: Batty & Taylor, 2003).

In the emotional face processing literature there is also evidence of different activation in emotional faces in later time windows (Eimer & Holmes, 2007), an activation that may be modulated by familiarity of expression (Balconi & Pozzoli, 2003). For a detailed discussion on the N170 and other face related components see experiment 2.

2. *Experiment B. Social Inferencing*

Socially relevant triggers in language are expected to elicit a late response related to semantic processing (Federmeier, 2014). In studies examining semantic processing it is noted that the modulation of attention associated with specific triggers in the semantic processing of a sentence is expected to elicit the N400 component or the Late Positivity component (Federmeier, 2014). In the case of language containing humor, the relevant trigger is the moment that the funny part of a humorous presentation is perceived (Feng, Chan, & Chen, 2014). Since the number of trials was not possible to create a clear waveform and the timing of events was not accurate on a millisecond level, a time frequency or frequency band analysis was used to determine possible differences in frequency bands between conditions.

Behavioral measurements were performed and analysed in the Statistical Package for the Social Sciences- IBM SPSS 24. EEG signal segments were processed with Brain Electrical Source Analysis – BESA 5.3 (www.besa.de) software. Averaged segments were imported into MATLAB where a Fast Fourier Transform analysis together with a Pwelch function calculation took place so that a single power measure for each wave band was extracted.

Differences between age groups on ERP Data on both experiments were also extracted and compared statistically with behavioural data to distinguish similarities and differences in measurements between behavioural measurements and EEG data (ERP amplitudes, frequencies). For further descriptions on these analyses refer to experiment 4.

Chapter III

Experiment 1: Neurocognition and SC in educated adults

Summary of Experiment 1

Aging is a process that affects neuropsychological functions and specifically is said to first affect functions located at the frontal/prefrontal lobes such as EF or even SC. In this study twenty eight older adults were matched in gender and years of education with twenty seven young adults and were tested in a series of neuropsychological tests measuring memory language and EF as well as in a series of experimental SC tests. Results show significant differences in performance between age groups favouring young adults in verbal and spatial memory, executive functioning and emotion recognition in animated stimuli, but no differences in performance in still emotion recognition stimuli and language measures, thus supporting a frontal lobe compensation hypothesis.

It is widely acknowledged that brain aging in its natural course does involve certain changes in cognitive processing mainly due to brain cell loss and decay that cannot be recovered. It has been a very common observation in studies using neuroimaging that older people use a larger area of their brain to process the same tasks than their younger counterparts (Knyazev, 2007). This reflects a slower processing speed and an EF impairment that leads to a working memory deficiency (Reuter-Lorenz & Cappell, 2008).

Despite these changes, older adults with a greater degree of cognitive reserve (i.e., the mind's ability to use strategies and compensate for pathological changes occurring in the brain through the use of active compensatory strategies; for a more complete explanation please refer to Whalley, Deary, Appleton, & Starr, 2004) tend to maintain their cognitive abilities and perform well on measures of memory and executive functioning (Giogkaraki, Constantinidou, Michaelides, 2013). Certain aspects of language abilities remain largely intact through aging and often times can be used to compensate for other cognitive changes it is yet to be examined in different perspectives how SC, a concept that incorporates both EF and language processing is affected by aging.

In this study we tested adults with higher education and compared them with young matched controls on several neurocognitive and SC measures. Metaxas (2015), who used a similar test battery has underlined the importance of education as a factor leading to better results in cognition in aging. In the present study, in which education was controlled for by means of matched samples, aspects of cognition and SC in educated adults will be examined through performance in neurocognitive and SC tasks.

Purpose and Hypotheses

The primary aim of this study was to investigate the differences between younger and older adults on SC and relevant neurocognitive tasks. Based on previous reports (Reuter-Lorenz & Cappell, 2008) and by Metaxas (2015), we expected that older participants would exhibit significantly poorer performance in memory and executive functioning as compared to their younger counterparts. However, older adults were expected to perform similarly to younger adults in tests assessing language abilities because of the education level of the sample (at least 12 years of education).

Older participants were expected to show significantly poorer performance on emotion recognition as measured by accuracy and reaction time (Carstensen & Mikels, 2005) in comparison to their younger counterparts. Furthermore, different patterns of performance were expected to emerge between the two age groups in the processing of negative emotions as measured by accuracy and reaction time, with older adults being less accurate and requiring more time than their younger counterparts.

It was hypothesized that social inference tasks that are contextually and ecologically based involve several processes in addition to language comprehension, including complex image processing and EF. Despite that, being a mainly language comprehension task, it was expected that there would be no differences in humor perception between the two age groups as measured by accuracy and reaction time of funny vs. unfunny items.

Methods

Participants

Participants consisted of two different groups divided by age and matched in gender and years of education. Twenty eight older adults (15 females, 13 males) were matched with twenty seven young adults (15 females, 12 males) in gender and years of education. Table xx presents age groups descriptives in years of education.

Table 2 .Descriptives for years of education for the two age groups

Group	N	Min	Max	Mean (SD)

Older Participants	28	12	20	14.93 (2.403)
Younger Participants	27	12	20	15.37(2.133)

A t-test between groups on years of education was not significant, *t (53)*=.720, *p*=.475. Participants had no prior history of neurological problems.

Participants were also asked to report possible use of medication or a mood disturbance which could affect their performance. The sample size calculated to reach an effect size of d=0.8 for t-tests was 19 participants per group. For a repeated measures ANOVA with an effect size of d=0.85 the sample size was calculated to 16 participants per group (calculations were made by G-Power 3.1 software). Twenty participants per group were recruited in the present study.

Table 3. Descriptives for target group (older participants) on the Geriatric Depression Scale and number of medicines taken.

	N	**# >0**	**Max**	**M**	**SD**
GDS	28	19	8	1.71	2.0
Medicine	28	21	3	.78	1

The cut-off for the GDS was 3/15. Older participants who had scored over 3 on the GDS were further screened for depression symptoms and were not qualified for a diagnosis. Their neurocognitive performance was on the average or above average range on all tests according to their age and years of education. Mood disturbances were justified due to recent life events such as serious illness or death of a spouse. Medication that was reported was mainly antihypertensive medication and lipid lowering medication. Younger participants had no reports of clinical depression symptoms or current medication consumption.

General cognition screening

The general cognition screening tool that was used, was aimed at establishing a cut-off point as an inclusion/exclusion criterion. Despite this, in some cases in written performance on the MOCA was lower than 26/30, all other test results were within the normal range, so these cases were included.

Table 4. Descriptives for both groups on the Montreal Cognitive Assessment Test

	N	**Min**	**Max**	**M**	**SD**
Older	28	24	29	25.89	1.37
Younger	27	23	30	27.1	2.4

*P=0.031

An independent-samples t-test was conducted to compare groups on the MOCCA test scores. Levene's test indicated unequal variances (*F*= 4.54, *p*= .038), so degrees of freedom were adjusted from 53 to 41.There was a significant difference in the scores for different groups favouring younger adults; *t*(41)= -2.23, *p* = 0.031.

Measures

Participants were tested in a series of neurocognitive and SC tests as well as two experimental tasks.

Neurocognitive tests (for a detailed description of each test see general methods section)

Montreal Cognitive Assessment test (MOCA) (Nasreddine, 2010)

Hopkins Verbal Learning test HVLT (Brandt, 1991)

Logical Memory test LM (Wallace, 1984)

Symbol digit test SDT (Smith, 1968)

Trail Making Test - Trails A, Trails B (Bowie & Harvey, 2006)

Rey Osterrieth Complex Figure test - Rey (Shin, Park, Park, Seol, & Kwon, 2006)

Peabody Picture Vocabulary test PPVT (Dunn & Dunn, 1965)

Controlled Oral Word Association Test – COWAT (Ruff, Light, Parker, & Levin, 1996)

Towers of Hanoi mental task (TOH)

SC experimental tests

The Reading the Mind in the Eyes test – eyes test (Baron-Cohen et al., 2001)

The Cambridge Mindreading in the face test CAM faces (Golan et al., 2015)

The Cambridge Mindreading in the voice test CAM voice (Golan et al., 2015)

Speeded Movies Clips test (Metaxas et al., 2016)

Cypriot Proverbs test – Proverbs (Metaxas, 2015; Metaxas et al., 2016)

Experimental tasks -behavioural measures

Behavioral measures on the experimental tasks will also be examined in this experiment in comparison to age group (for a description of the experimental tasks look at the general methods section).

Joyful facial expression accuracy and reaction time

All but joyful facial expression accuracy and reaction time

Humour discrimination (HD)- funny items reaction time, accuracy

Humour discrimination (HD) - Not funny items reaction time, accuracy

Procedure

Participants were recruited with a snowball sampling method to match the prescribed criteria and be able to volunteer for participation. The examiner was the same in all cases (Author). Participants were tested during two separate testing sessions. Session 1 consisted of all neurocognitive and social cognitive tests and lasted between 2 and 2.5 hours. Testing took place in a quiet location which met the test administration requirements and was also convenient to the study participants. All neurocognitive tests were given in a paper and pencil form and all SC tests were given in a computerised form. The Towers of Hanoi test was given in a physical form. Experimental measures were given on a separate meeting at the Centre of Applied Neuroscience University of Cyprus where EEG measures were simultaneously recorded. All tests were given in the same order (for a detailed description of all tests and tasks as well as the order of tests refer to the general methods section).

Research Questions

Will older adults perform more poorly than younger adults on neurocognitive and SC measures?

Will older adults have significantly lower accuracy scores and require significantly more time in processing emotional expressions?

Will the performance of older adults on humor discrimination be similar to that of their younger counterparts?

Statistical Analysis

For the purposes of this experiment means comparisons of test measures were conducted, mainly t-tests and analysis of variance (ANOVA) tests. All analyses were conducted with IBM SPSS statistics 24.

Results

Memory verbal learning

Table 5. Descriptive statistics for memory tests

	Mean (SD)	
	Older (n = 28)	Younger (n = 27)
HVLT 1-3trial	22.86 (4.06)	24.19 (4.18)
HVLT Delayed recall*	7.11 (1.81)	8.59 (2.26)
HVLT recognition	11.21 (1.03)	11.59 (.80)
LM Immediate recall**	22.86 (3.39)	26.70 (7.58)
LM Delayed Recall***	19.71 (4.63)	23.56 (7.37)

*p=0.009 **p=0.021 ***p=0.024

An independent-samples t-test was conducted to compare groups on test scores. Older participants' performance was significantly lower on the HVLT delayed recall scores and Logical Memory Immediate and Delayed Recall scores. Levene's test indicated unequal variances for logical memory immediate recall (*F*=9.77, *p*= 0.03), so degrees of freedom were adjusted from 53 to 36. There was a significant difference in the scores for different groups; HVLT delayed recall *t*(53)= -2.7, *p* = 0.009, d=-0.73(α′ = α/k = 0.015); Logical Memory immediate recall *t*(36)= -2,41, *p* = 0.021, d=-0.65(α′ = α/k = 0.025); Logical Memory delayed recall *t*(53)= -2.32, *p* = 0.024, d=-0.63(α′ = α/k = 0.025).

Spatial constructional ability and memory

Table 6. Rey Osterrieth Complex Figure Test descriptives

	Group	N	Mean (SD)
Rey Copy*	Older	28	34.00(2.13)
	Younger	27	35.26(1.79)
Rey Immediate recall	Older	28	22.30(17.44)
	Younger	27	23.04(7.15)
Rey delayed recall**	Older	28	16.50(5.46)
	Younger	27	26.81(14.84)
Rey recognition***	Older	28	7.79(1.79)
	Younger	27	9.30(1.46)
Rey false positives	Older	28	.86(.80)
	Younger	27	.89(1.05)

*p=0.021 **p=0.001 ***p=0.001

An independent-samples t-test was conducted to compare groups on test scores. Older participants performance was significantly lower on the Rey Osterrieth Complex figure Copy task, *t*(53)= -2.37, p = 0.021, d=-0.64, the Rey Osterrieth Complex figure Delayed Recall task *t*(53)= -3.44, *p* = 0.001, d=-0.93(α′ = α/k = 0.015), and the Rey Osterrieth Complex figure Recognition task, *t*(53)= -3.42, p = 0.001, d=-0.92(α′ = α/k = 0.015).

Executive functioning

Table 7. Descriptives for executive functioning tests

	Group	N	Mean (SD)
Symbol Digit Modalities test *	Older	28	39.82 (6.266)
	Younger	27	48.59 (9.275)
Trails A (time in sec)**	Older	28	48.46 (15.784)
	Younger	27	31.30 (10.745)
Trails B (time in sec)***	Older	28	107.46 (33.963)
	Younger	27	80.11 (37.502)
TOH number of moves	Older	21	72.29 (22.318)
	Younger	23	78.70 (33.662)

TOH time in sec	Older	21	435.48 (312.163)
	Younger	23	412.00 (216.983)

*p=0.00 **p=0.00 ***p=0.006

An independent-samples t-test was conducted to compare groups on test scores. Performance on the Symbol Digit Modalities and the Trail Making A and B scores resulted in significant group differences favouring young adults. Levene's test indicated unequal variances for Symbol Digit Modalities test (*F*=5.82, *p*= 0.019), so degrees of freedom were adjusted from 53 to 45.44. Significant differences were maintained as follows: Symbol Digit Modalities *t* (45)= -4.12, *p* = 0.001, d=-1.22 (α′ = α/k = 0.01) ; Trail Making A *t*(53)= 4.69, *p* = 0.001, d=1,26 (α′ = α/k = 0.01); Trail Making B *t*(53)= 2.84, *p* = 0.006, d=0.76 (α′ = α/k = 0.01).

Emotion recognition

Table 8. Descriptives for emotion recognition tests

	Group	N	Mean (SD)
Eyes Test emotion recognition	Older	28	22.21 (3.715)
	Younger	27	23.52 (3.215)
Eyes test gender accuracy	Older	28	32.61 (2.713)
	Younger	27	33.67 (1.941)
CAM faces*	Older	28	30.11 (5.050)
	Younger	27	35.11 (4.484)
CAM voice**	Older	28	31.32 (3.465)
	Younger	27	34.00 (2.287)
Speeded Movie Clips Accuracy*	Older	26	56.69 (8.049)
	Younger	26	70.35 (5.433)
RTime on emotional faces experiment (all but joy)	Older	25	1258.36 (499.238)
	Younger	22	975.27 (467.846)
Accuracy on emotional faces experiment (all but joy)***	Older	25	80.08 (11.957)
	Younger	22	88.86 (5.783)

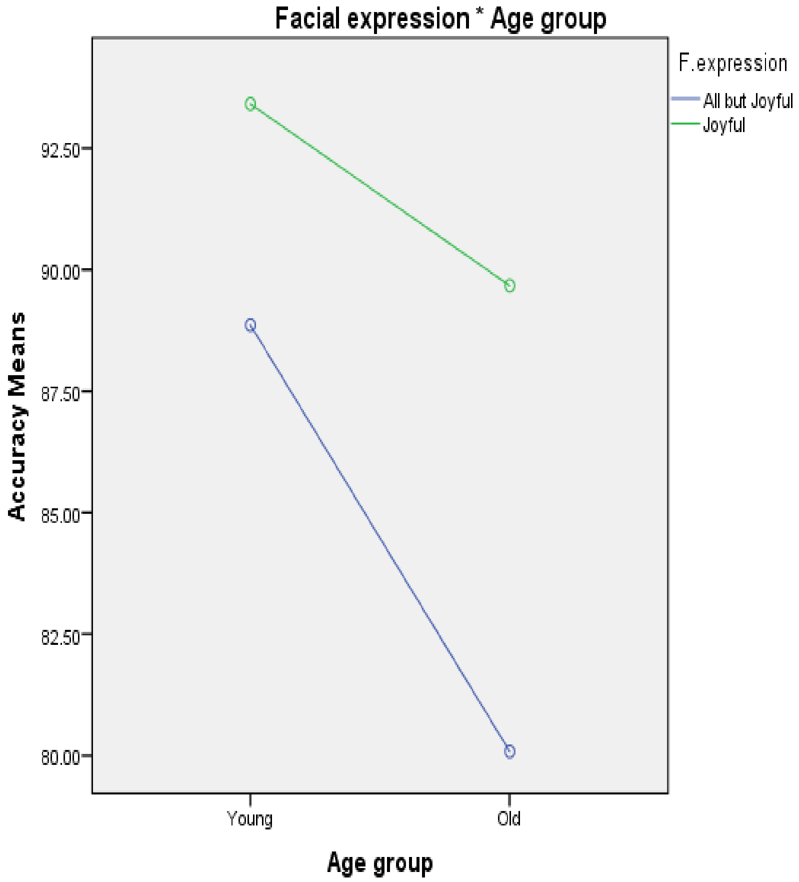
Reaction time on Joyful Emotional faces	Older	25	1224.48 (426.509)
	Younger	22	1162.00 (1117.219)
Accuracy on joyful emotional faces^^	Older	25	89.67 (8.045)
	Younger	22	93.41 (3.892)

*p=0.00 **p=0.01 ***p=0.02 ^^p=0.046

An independent-samples t-test was conducted to compare groups on test scores. CAM faces CAM voice and Speeded movie clips scores resulted in significant group differences. Levene's test indicated unequal variances for CAM sounds (F=4.88, p= 0.031), so degrees of freedom were adjusted from 53 to 47.Older participants performance was lower on the CAM faces, $t(53) = -3.88$, $p = 0.00$, d=-1.05 ($\alpha' = \alpha/k = 0.01$), CAM sounds, $t(47)= -3.4$, $p = 0.01$, d=-0.99 ($\alpha' = \alpha/k = 0.01$) and Speeded movie clips, $t(50)= -7.17$, $p = 0.00$, d=-2.02 ($\alpha' = \alpha/k = 0.01$).

Behavioral data on the emotion recognition task, accuracy and reaction time were entered in a repeated measures ANOVA with group as the between subjects factor. Older participants were significantly less accurate in identifying joyful vs all but joyful facial expressions, $F(1,45)=33,38$, $p=0.00$ $\eta^2= .426$. ($\alpha' = \alpha/k = 0.025$). There was also a significant interaction between type of stimuli and group, $F\ (1,45) =1.03$, $p=0.045$ $\eta^2=.086$. Figure 6 is the graphic display of the interaction.

Fig 6. Interaction between Stimulus type (All but Joyful facial expressions Vs Joyful facial expressions) and groups on the facial expression recognition experimental task



Language abilities

Table 9. Descriptives on language abilities tests

	Group	N	Mean (SD)
COWAT animals*	Older	28	14.07 (2.788)
	Younger	27	16.59 (4.449)
COWAT words from Φ	Older	28	11.00 (3.600)
	Younger	27	11.11 (2.847)
COWAT objects	Older	28	18.54 (4.702)
	Younger	27	20.48 (3.435)
COWAT fruits**	Older	28	13.61 (2.393)
	Younger	27	15.22 (2.764)
PPVT	Older	28	28.43 (2.150)
	Younger	27	26.89 (4.228)
Cypriot proverbs test	Older	26	23.46 (2.996)

	Younger	25	22.96 (3.075)

*p=0.014 **p=0.024

Performance on language tests presented no significant differences apart from the Controlled Word Association Test Animals *t*(53)= -2.53, *p* = 0.014 and Fruits *t*(53)= -2.32, *p* = 0.024 tasks.

Humor discrimination task

Table 10. Descriptives on the humour discrimination task

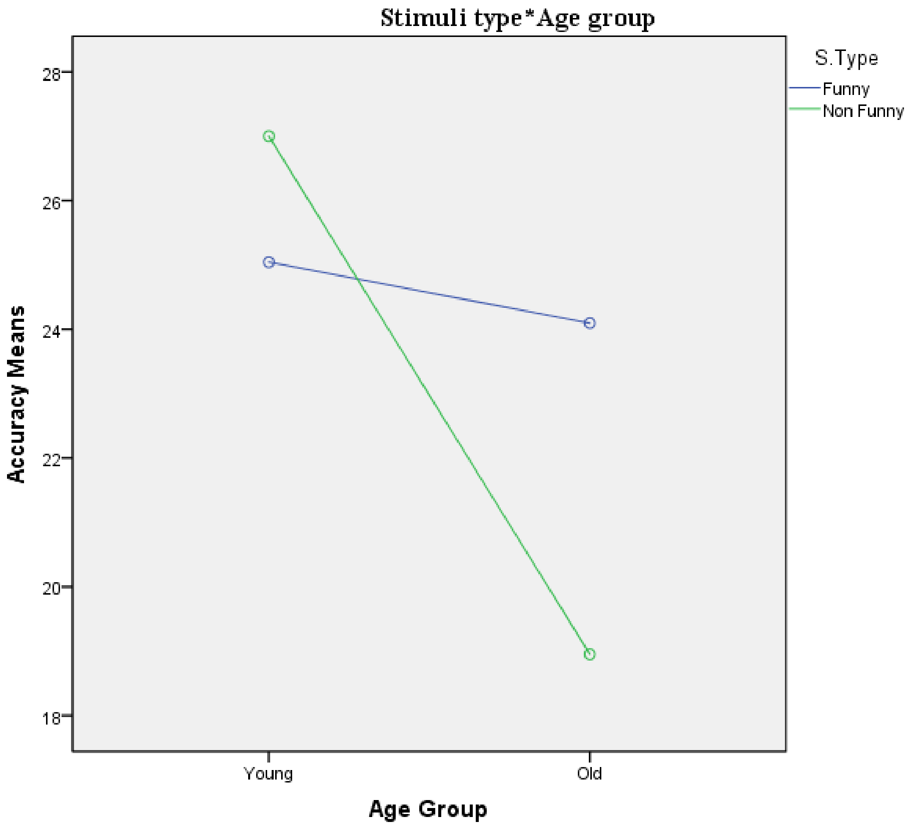
	Group	**N**	**Mean number of correct answers (out of 35) (SD)**
HD accuracy funny items	Older	21	24.10 (6.472)
	Younger	23	25.04 (6.079)
HD Reaction time funny items	Older	21	4002.10 (7583.539)
	Younger	23	1850.30 (1031.024)
HD Accuracy NON funny items*	Older	21	18.95 (7.386)
	Younger	23	27.00 (4.661)
HD Reaction time NON funny items**	Older	21	2375.62 (812.937)
	Younger	23	1826.57 (801.616)

*p=0.00 **p=0.29

Behavioral scores on the Humor Discrimination experiment were entered in a repeated measures ANOVA with group as the between subjects factor. Overall, older participants were equally accurate with younger participants in identifying funny or not funny items F(1,42)=1.02, *p*=0.318 . However, there was a significant interaction of type of funny element*group (*F*(1,42)=5.06 , *p*=0.030 η^2=.103). This interaction suggests that the two groups have different profiles in performance, with younger adults having much better accuracy for non-funny items as compared to older adults. Figure 7 is the graphic plot of the interaction effects. As it is shown in the figure, in non-funny items the two groups have an attenuated difference between means in accuracy.

To examine this further, a t –test between groups was performed only on non-funny items. Degrees of freedom reduced from 42 to 33 because Levene's test indicated unequal variances, *F*=9.01, *p*= 0.005, the difference between groups was significant *t*(33)=-4.27 , *p*=0.000 d=-1.4.

Fig 7. Interaction between type (funny or not) by group (old and young) in behavioural measures



Discussion

This study aimed at examining whether aging affects neuropsychological functions - i.e. memory, executive functions measures and language tests- as well as SC measures (i.e. emotion recognition in still and dynamic pictures and in the voice). Twenty eight older adults were matched with twenty seven young adults in gender and years of education and given a series of neuropsychological and SC tests. Results show that older people perform significantly more poorly in tasks of verbal and spatial memory, in spatial constructural ability, visual scanning and tracing – abilities belonging to the EF - and in emotional recognition measures with animated stimuli (videos or movie vignettes). The groups did not differ significantly on language measures or still images emotion recognition performance. Knowledge on neurocognitive modules affected by aging and compensatory mechanisms can be provided although further analyses will take place in the following experiments of this study.

As expected, older participants performed significantly more poorly in measures of memory and executive functioning as compared to their younger counterparts. Also, as expected, the difference between groups was not significant on language tasks that did not include a processing speed and executive functioning element. The present findings provide further support towards the idea of an executive function decline leading to difficulty encoding in long term memory (Zelazo et al., 2004). This could also be evidence towards the frontal lobe hypothesis in aging (West, 2000). The focus on executive functions which are considered to be closely related to frontal lobe decline is apparent in verbal learning test results where differences between groups are significant in delayed recall. Also, in timed EF tasks such as the Trail Making and Symbol Digit tests and on the spatial construction and memory task, construction and delayed recall and recognition are significantly different between groups favouring younger adults. This assumption will be further investigated together with the role of language abilities and SC in Experiment 4 of this study.

Concerning the Humor Recognition task, although the groups did not differ on language test results, they did differ in their performance on the humour recognition task. Specifically, the funny element seems to facilitate stimulus processing in older adults resulting in equally accurate processing with young adults. During the non-funny items, older participants make significantly more errors than their younger counterparts. The present findings support a hypothesis where the search for funny elements in non-funny images, is more demanding in older adults who cannot depend on a robust processing system to support them, thus supporting the lack of inhibitory processing in aging (von Hippel, 2007). Further investigation on humor aspects in aging will be done in experiment 3 of this dissertation.

As expected, older participants exhibited lower performance on emotion recognition tasks. The CAM and the Speeded movies test as well as the experimental emotion recognition task differentiated the two groups. This is in support of emotion recognition as a process that engages frontal lobe networks. This assumption will be further examined in Experiment 2 which incorporates electrophysiological data. In the present study there was a group by type of emotion interaction. Older participant accuracy was significantly lower when processing all-but-joyful emotional faces as compared to joyful expressions. These results seem to be in support of the positivity hypothesis in aging (Mather & Carstensen, 2005) although further investigation on the neurophysiological underpinnings of this behavioural phenomenon will be provided in experiments three and four.

The results of this experiment provide overall knowledge on basic hypotheses on human aging, such as the frontal lobe hypothesis. Good attributions are also made in the area of how compensatory mechanisms work in relation to executive functioning and SC modules. Further analyses on aging neurocognition and SC in experiment 4.

Chapter IV

Experiment 2: Electrophysiology of facial expression processing in young and older adults

Summary of Experiment 2

Emotional expression in faces is a very common measurement of SC. In electrophysiology, the N170 component and later components are reported to be modulated by facial expression (Eimer & Holmes, 2007). Aging also affects emotion recognition although joyful faces appear easier to process (Metaxas, 2015). The present study examined the electrophysiological underpinnings of facial expression processing in young and older adults. Two groups of participants, twenty five older adults and twenty two young adults matched in gender and education level completed a facial expression recognition task. Reaction time and accuracy were obtained along with N170 ERP recordings. Behavioral results showed an interaction of conditions meaning that older participants had a significantly lower accuracy in identifying all-but-joyful facial expressions but in joyful expressions the performance was the same. ERP results yielded a N170 component in parietal-occipital electrode sites bilaterally. These are areas of visual integration and association. In those electrode sites, significant differences in amplitude appear, with all-but-joyful faces having higher amplitudes and/either a stimuli/ type by age group interaction with older adults showing higher amplitude in joyful faces. The opportunity to process joyful faces appearing in behavioral as well as electrophysiological data contributes to the support of a positivity effect during aging.

Emotional facial expression has been reported to trigger an increased ERP positivity as early as 150 msec after the presentation of an emotional face in comparison to neutral faces (Eimer & Holmes, 2007). The type of the emotional expression depicted on the face has been reported to create different activation patterns, with fearful faces presenting an amplified and later N170 (Batty & Taylor, 2003). Later components (250- 300 msec) are also reported to be modulated by emotional expression type, with negative expressions showing higher peak amplitudes (Balconi & Pozzoli, 2009; Holmes et al., 2005).

The N170, an ERP component that is considered to be a face-specific component, is considered to reflect the very first perception of a face (Rossion & Jacques, 2011). It appears mainly in temporal parietal and occipital electrode sites (Rossion & Jacques, 2011) contralateral to the visual hemifield that the face is depicted on, or bilaterally (Towler & Eimer, 2015). The early appearance of the N170 together with findings in a number of studies leads to a suggestion that it only involves the structural components processing of a face (Eimer & Holmes, 2002; Holmes et al., 2005). Other studies though, have found that emotional expression has been able to modulate the N170 resulting in differences in amplitudes between emotional expressions or between emotional and neutral faces (Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCandliss, 2007). There is a suggestion in the literature that this discrepancy in results stems from the reference used, suggesting that a mastoid reference does not result in emotion modulation of the N170 whereas an average reference does (Rellecke, Sommer, & Schacht, 2013). Despite this, in support of the N170 being modulated by emotional expression, are also studies with clinical populations presenting abnormalities in emotional processing such as patients diagnosed with schizophrenia, which show lower amplitudes on the N170 when processing emotional expressions in comparison to healthy controls (Feuerriegel, Churches, Hofmann, & Keage, 2015; Ibáñez et al., 2012).

Later ERP components that are more associated to attentional and emotional processes are also reported to be modulated by facial expression. There is a positivity identified around 250msec postimulus in a number of papers (Eimer & Holmes, 2007), or a negative peak around 250-270msec postimulus (Sato, Kochiyama, Yoshikawa, & Matsumura, 2001). There is also a suggestion that the N400 is modulated by faces, thus suggesting that a semantic process similar to that of a word processing may be happening at that time frame (Barrett & Rugg, 1989).

Emotional faces processing in the aging literature includes emotion recognition in facial expression. Deficiencies associated with normal aging are largely attributed to the frontal lobe hypothesis of aging (Gunning-Dixon et al., 2003). Faces processing in natural settings involves a great part of SC as well as executive functioning processes (Adolphs, 2001). It also appears that older adults do employ frontal lobe networks to a greater degree than younger adults when processing emotional faces (Gunning-Dixon et al., 2003). Larger activation of the frontal lobes in older adults in cognitive processing that involves different brain areas in young adults is attributed to the compensational abilities of the older brain.

As indicated in Chapter 1, a prominent hypothesis in aging and emotional processing is the positivity hypothesis. This hypothesis is based on a series of observations in research that older people are more prone to choose positive emotional experiences and ignore the negative ones (Hajcak, Weinberg, MacNamara, & Foti, 2011). This is usually attributed to motivational reasons, supporting a hypothesis that a coping mechanism is built gradually that focuses on positive experiences in life. This hypothesis is sometimes attributed to results in the face expression discrimination literature, although alternative hypotheses that place joyful faces in a privileged position in processing do exist, such as the hypothesis that recognition of the smile is developmentally salient thus broadly established and easier to process, thus later to decline (Bowlby, 1958; Vygotsky, 1978) .

Metaxas (2015), has studied behaviorally emotional expressions in aging in a series of tests which are also included in this study (see experiments 1 and 4), in a larger- more scaled according to age- sample from a population with the same characteristics as this study. He concluded that although positive emotions remain easier to process through aging, can be attributed to a simpler explanation than the motivational reasons explanation provided in literature because when the complexity of the task increases, the positivity effect disappeared, suggesting that positive emotions are only easier to process and not motivationally important to attend to. This study, by examining performance in an educated adult matched in education and gender sample attempts to examine whether Metaxas's finding will be replicated. Added to that this study aims at examining the same observation by using electrophysiological markers thus extracting conclusions as to which processes might be involved in it and in which manner.

In this study we attempted to determine whether or not age group performance in emotional recognition tasks, is reflected in early electrophysiological measures. For this purpose, an experimental "emotional faces" task was conducted. Participants were asked to distinguish six basic facial expressions in static pictures. It is expected that processing joyful vs. non joyful expressions will result in significant differences in peak amplitude on the N170 or later components, for all participants (Balconi & Pozzoli, 2003). Moreover, according to the positivity hypothesis of aging reported in the literature (Mather & Carstensen, 2005), it is expected that we will observe significant differences between age groups during the processing of negative facial expressions as measured by peak amplitude. Older adults will demonstrate higher peak amplitudes for negative facial expressions than younger adults and non-significantly different amplitudes for positive expressions, (as seen in Mather & Casternsen, 2005).

Methods

Participants

Twenty five older participants (13 females, 12 males) were matched with twenty two young adults (13 females, 9 males) in gender and years of education. Participants were chosen from a larger sample of participants; left handed individuals and participants with EEG signals containing large amounts of noise were excluded by the noise extraction routines provided in BESA (https://www.besa.de/). All study participants had at least twelve years of education. In table 11 you can see the descriptives on years of education for both groups.

Table 11. .Descriptives for years of education for the two age groups

Group	N	Min	Max	Mean (SD)
Older Participants	25	12	20	15.55 (2.220)
Younger Participants	22	12	20	15.08(2.361)

A t-test between groups on years of education was not significant, *t(45)*=.693, *p*=.492. Participants had no prior history of neurological or psychiatric problems. The sample size calculated to reach an effect size of 0.85 on repeated measures ANOVA between subjects, within subjects and interaction effects was minimum 16 participants per group (calculations were made with G-Power 3.1 software)

Procedure

Participants were recruited with a snowball sampling method. Participants were informed of the procedure (concerning cognitive assessment and EEG measurement) and signed a consent form. The recommended standard procedures for the placement of the 64 electrode system cup were followed. Participants attended a brief training session to ensure that they were able to follow the experimental procedures of the study. All stimuli were computerized and special instructions for not moving were given in order to minimize noise.

Research Questions

Is there a difference between the two groups in the peak amplitudes of the N170 component?

Are there different patterns of N170 peak amplitude between the two groups depending on the type of stimulus to be processed?

Materials

Task description

Forty five photos of masked emotional faces taken from an existing database (Ekman, Friesen, & Hager, 2002), were screened one by one followed by a screen depicting a word –

an emotion while recording EEG measurements. The following emotions were depicted: joy, sadness, anger, surprise, disgust and fear. Participants were asked to report if the word was correctly reporting the facial expression depicted on the previous screen or not by choosing between two buttons on the keyboard. Blank interval screens of 800msec duration appeared between trials. Forty-five photos were presented in a repeated manner interchangeably with all combinations of emotion-words twice so that the task reached 628 trials.

Fig 8. Example of a congruent emotion recognition trial (emotional expression depicting fear and the word fear on the next screen- participants had to press a button to report its correct)

SCREEN1 **SCREEN2**

Fig 9. Example of an incongruent emotion recognition trial (emotional expression depicting fear and the word disgust appearing on the next screen): participants had to press a button to report it's incorrect.

SCREEN1 **SCREEN2**

Electrophysiological measurements

All ERP measurements took place at the Center of Applied Neuroscience in the central campus of the University of Cyprus. The data acquisition equipment was a high-density EEG/ERP recording system, an unshielded 64-channel BIOSEMI Active-Two. Samples were taken on a 256Hz sample rate with an online average reference.

Analyses

All behavioral data on accuracy and reaction time were extracted and analyzed in SPSS. Electrophysiological data were cleaned from noise by eye inspection initially to remove bad channels and then by artefact rejection procedures in BESA to remove eye blinks and other muscle movement noise, waveforms were segmented and averaged for the sixteen pre-selected electrodes in the area where the N170 was apparent (O1,O2,Oz,PO7,PO8,POz,PO4,PO8,PO3,P1,Pz,P2,P4,P3,CP3,CP4) for an epoch of 0-500 msec and a baseline of -100msec to the presentation of the face stimulus waveform segments for each electrode were averaged in BESA. Peak detection was estimated by identifying the largest peak from 150-200msec postimulus conducted in BESA. This method was preferred instead of a peak on 170 msec because of the difference in number of trials between the two conditions resulting in more noise on the joyful faces trials. Peak amplitudes and latencies were extracted and entered in SPSS where further analyses took place. All waveform and power images were taken in BESA.

Results

Behavioral results

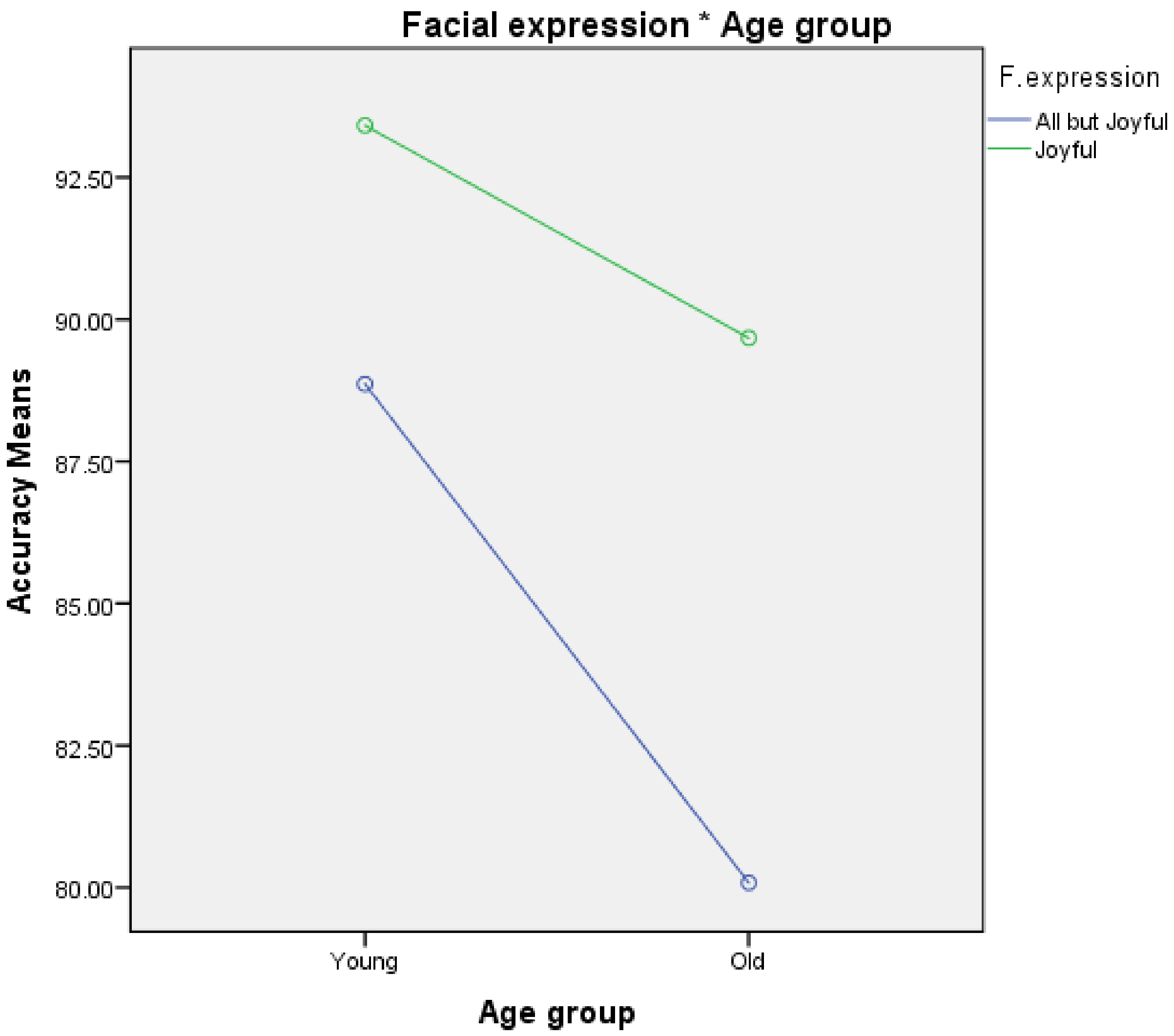
Table 12 *Means for behavioural measures of the emotional faces recognition experiment*

	Mean **(SD)**	
	N=25	N=22
Group	Older	Younger
Reaction Time on all emotional faces All but joyful	1258.36 (499.2)	975.27 (467.8)
Accuracy on all emotional faces All but joyful *	80.08 (12)	88.86 (5.8)
Reaction time on Joyful emotional faces	1224.48 (426.5)	1162.00 (1117.2)
Accuracy on joyful emotional faces**	89.67 (8)	93.41 (3.9)

**p*=0.02 ***p*=0.046

Behavioral data on the emotion recognition task, accuracy and reaction time were entered in a repeated measures ANOVA with group as the between subjects factor. Older participants were significantly less accurate in identifying joyful and all but joyful facial expressions, F(1,45)=33,38, p=0.00 η^2= .426. ($\alpha' = \alpha/k = 0.025$). There was also a significant interaction between type of stimuli and group, F (1,45) =1.03, p=0.045 η^2=.086. Figure 10 is the graphic display of the interaction.

Fig10.Interaction between Stimulus type (All but Joyful facial expressions Vs Joyful facial expressions) and groups on the facial expression recognition experimental task



ERP analyses

Peak amplitude data on averaged waveforms on each subject for the two conditions separately were entered a repeated measures ANOVA with type of stimuli (joyful vs all but joyful) as a within subjects factor and group (old vs young) as a between subjects factor. All trials were used as the comparison between correct and incorrect answers yielded no results. Electrodes in parietal-occipital electrode locations presented significant differences in amplitude in stimuli type with all but joyful having bigger amplitudes, and some in the same area presented also an interaction of group by type with older people having a significantly higher difference between types of stimuli.

Table 13. Mean N170 peak amplitudes for electrodes that presented $p<0.05$ in type of stimuli

Electrode site	**Mean amplitude (µV)**			
	Old Participants		Young Participants	
	Joyful	All-but-Joyful	Joyful	All-but-Joyful
P1	1.39	1.63	-1.03	-.23
PO3	-2.42	-2.33	-2.66	-1.73
O1	-6.37	-6.1	-5.71	-4.67
POz	-1.88	-1.57	-2.69	-1.40
PO4	-4.5	-4.29	-4.96	-3.22

Joyful faces presented significantly lower amplitudes marginally in PO3 $F(1,39)=4.5$, $p=0.040$, O1 $F(1,38)=6.55$, $p=0.015$, $\eta^2=.147$; PO4 $F(1,32)= 7.21$, $p=0.011$,$\eta^2= .184$and POz: $F(1,36)=11.47$, $p=0.002$, $\eta^2=.242$ (a was reduced to 0.01).

In P1 a significant difference was present in joyful faces as well as between age groups $F(1,38)=5.16$, $p=0.029$ (stimuli type) $F(1,38)=16.12$, p=0.00 (age group)

Table 14. Mean N170 peak amplitudes for electrodes that presented p<0.05 in stimuli type by group

Electrode site	**Mean amplitude (µV)**			
	Old Participants		Young Participants	
	Joyful	All-but-Joyful	Joyful	All-but-Joyful
POz	-1.88	-1.57	-2.68	-1.40
Pz	-2.63	-2.42	-.34	.42
CP4	-3.1	-2.43	-2.01	-1.27
P2	-1.28	-.92	-1.78	-.49
P4	-.01	-.53	-2.74	-2.17

A number of electrode sites presented a significant difference in the interaction between stimulus type and age group with older participants presenting an attenuated difference in amplitude: Pz: $F(1,38)= 5.72$, $p=0.022$ $\eta^2=.131$, CP4: $F(1,38)= 4.33$, $p=0.044$ $\eta^2=.102$, P2: $F(1,31)= 8.28$ $\eta^2=.211$, $p=0.007$, P4: $F(1,36)= 4.14$, $p=0.049$ $\eta^2=.103$, POz: $F(1,36)= 4.29$, $p=0.046$ $\eta^2=.106$. Below graphs show the averaged waveforms on two of these electrode sites (a was reduced to 0.01).

Fig11. Average waveforms for Pz on old and young participants (scale: 1µV)

** Amplitude numbers might be slightly different than the table due to averaging being conducted in different software.*

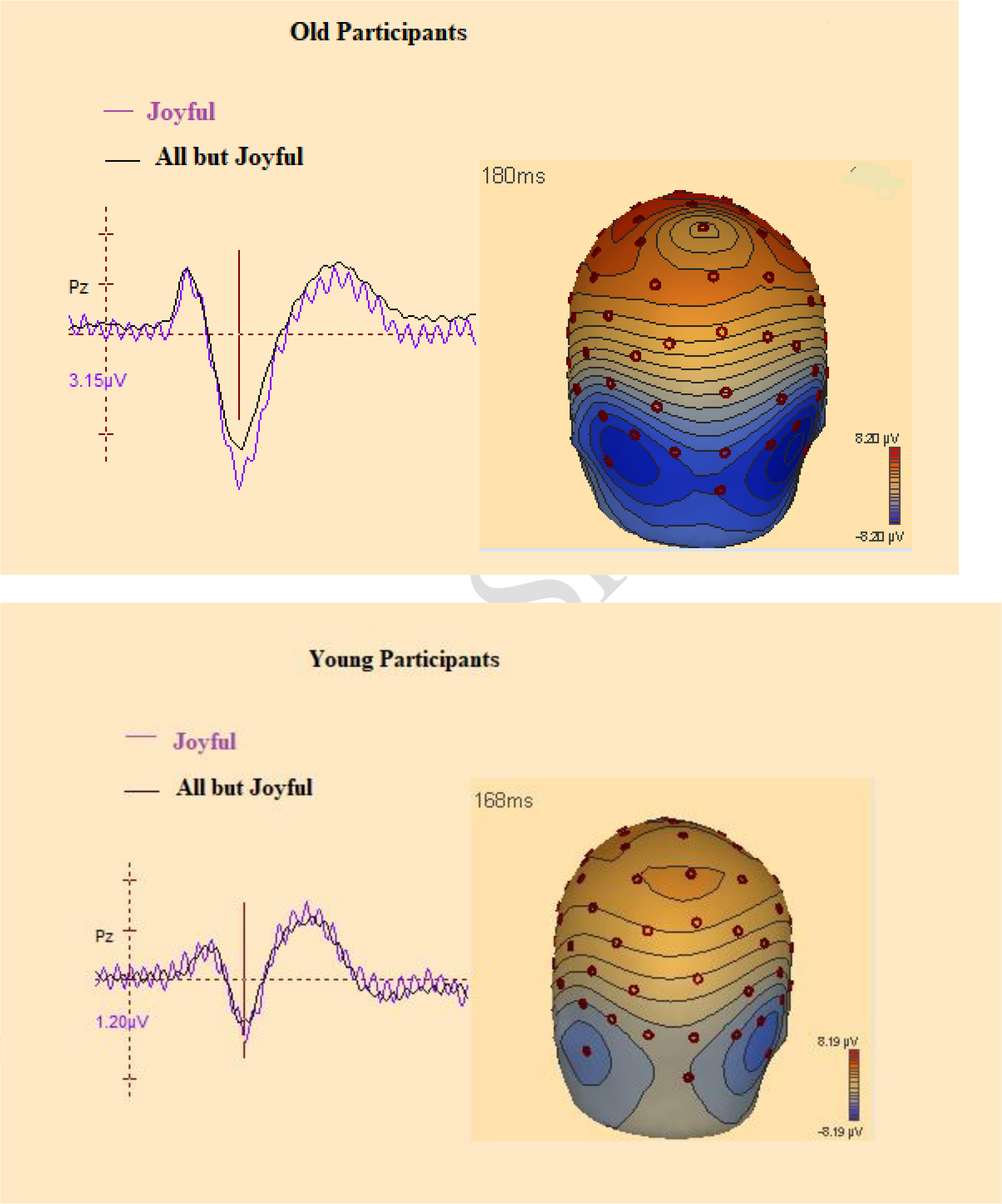
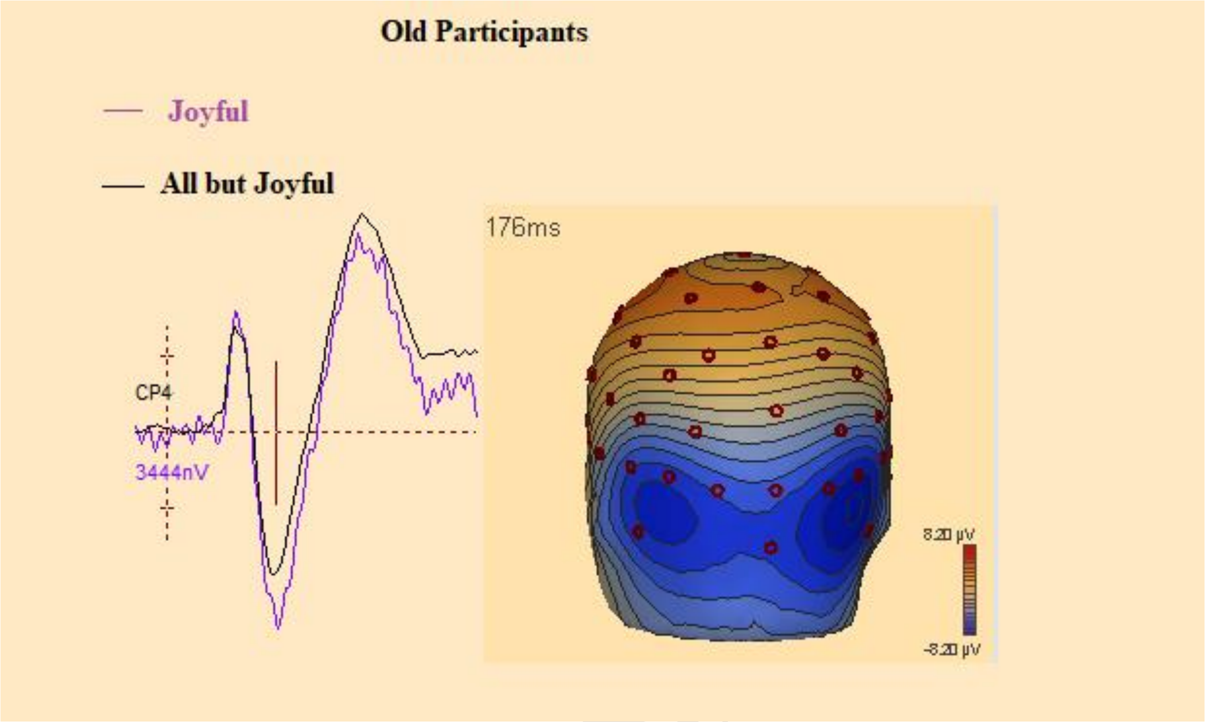
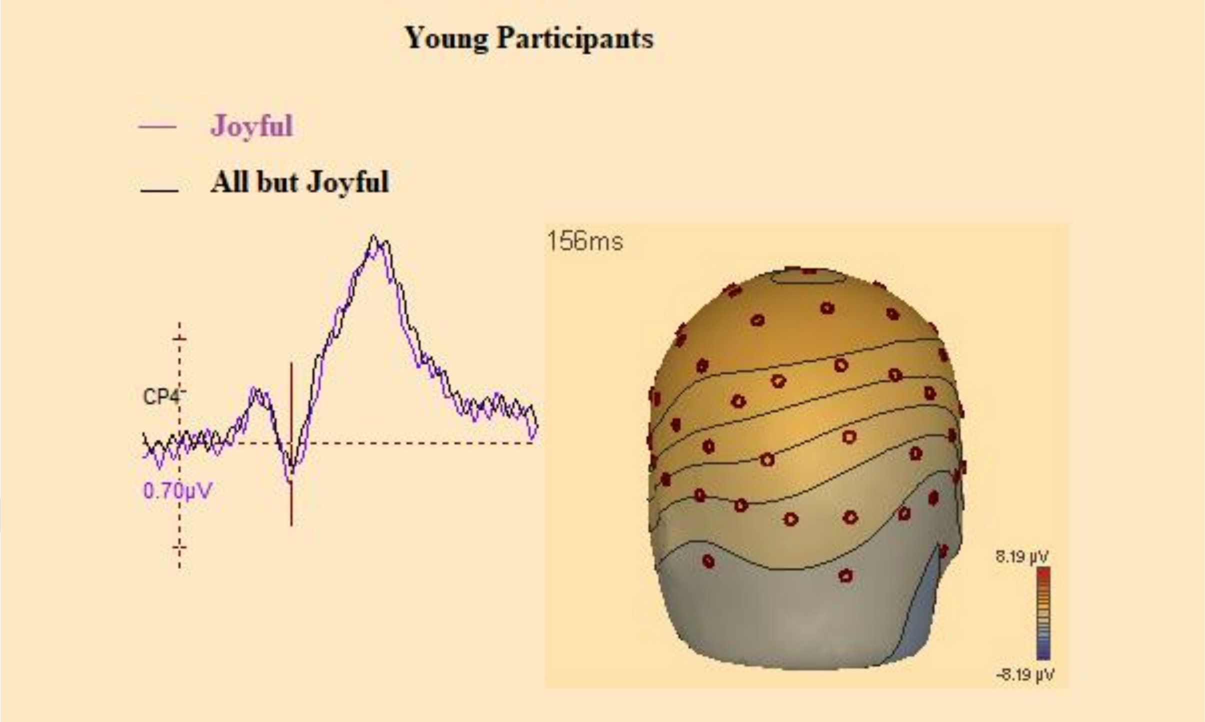


Fig12. Mean amplitudes on CP4 on the N170 (scale: 1µV)

** Amplitude numbers might be slightly different than the table due to averaging being conducted in different software.*

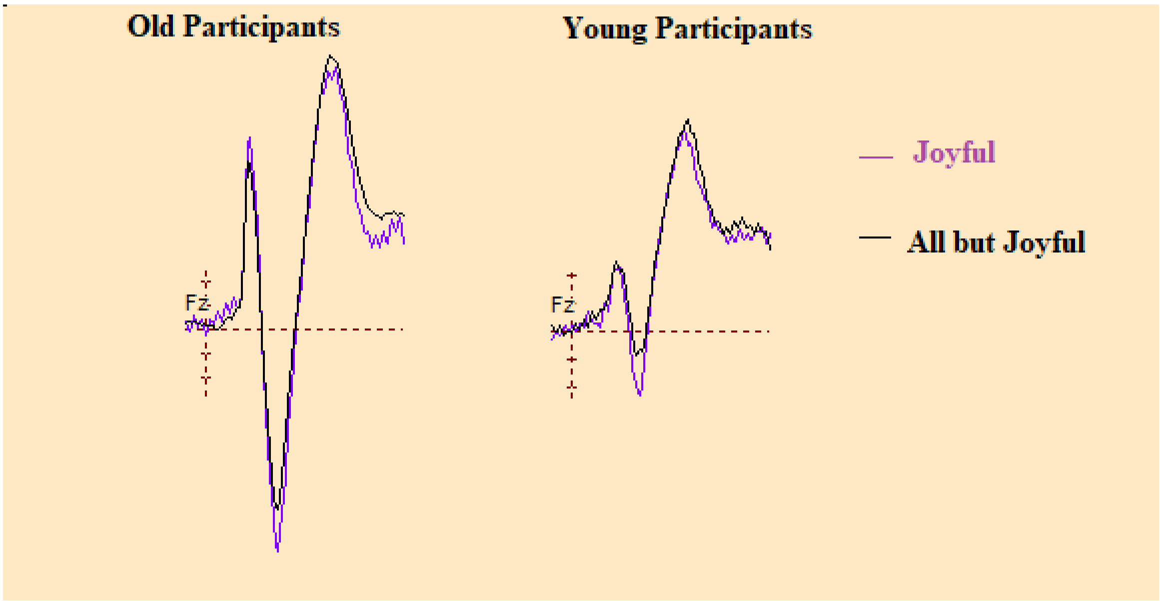




Late components

A later peak was also apparent around 270 msec in frontal electrodes as shown in the following figure

Fig13. Average waveforms for old and young participants on Fz (epoch: -50msec – 500msec scale: 1μV)



As it is shown in the figure, older people do have higher amplitudes on the second positive peak (on the figure it’s at 270msec), a peak which attenuates on frontal electrodes. On posterior electrodes the second peak is not as apparent. Analyses on this component were not made for the purposes of this study. Further details at discussion.

Discussion

This study aimed at examining the basic hypotheses of aging in electrophysiological components of facial emotional expression. Two groups of healthy participants, young adults and older adults conducted a facial expression discrimination task while being measured by EEG. Results show that joyful faces are easier to process by young and older people as measured by accuracy, but also as measured by amplitude even in early stages of processing such as 150-200 msec poststimulus. Furthermore, in both behavioral and electrophysiological measures, older people had a greater difficulty in processing all-but-joyful facial expressions, thus verifying the original hypothesis. The N170 component appeared in parietal-occipital electrode sites where significant differences were also found in all subjects in processing joyful vs all-but-joyful emotional expressions. This study is in support with other studies suggesting that the N170 is modulated by facial emotional expression (Blau et al., 2007). In electrode sites where the N170 is located, all participants were facilitated by joyful facial expression. This is in accordance with previous studies reporting that the N170 component in happy faces appears earlier and with a lower amplitude than fearful or surprised faces (Batty & Taylor, 2003) . The smile, or the joyful expression has a universal privilege in processing facilitation. Furthermore, a late peak is also apparent in data as reported in many studies (Eimer & Holmes, 2007) indicating that there is a continued evaluation process of the emotional expression.

Concerning aging, the present results contribute partly to a frontal lobe human specific compensation hypothesis (Gunning-Dixon et al., 2003) through the examination of processes that are said to be mainly processed by the frontal lobe. Further studies must establish this difference by using later ERP components which are located in frontal areas of the brain. Despite this, these results are in accordance with other studies using clinical populations which present abnormalities in emotional processing in behavioural measurements , where the N170 amplitudes appear different than in healthy controls (Feuerriegel et al., 2015; Ibáñez et al., 2012).

Overall, this study attributes to the investigation of emotion recognition declines happening with aging by providing an indication of an electrophysiological measure that can be used to examine emotion expression recognition in aging, and its relations to the behavioral performance discrepancies in emotional recognition tasks that is described in literature, as well as in the Metaxas (2015) study. On aging, this study's results support a positivity effect. Through behavioral data results as well as ERP results, the interaction between stimulus types by age group indicates that older adults continue to process effectively joyful faces similarly to younger adults. However, their ability to process other facial emotions is not at the same level as compared to the younger adults as demonstrated by differences in electrophysiological findings and behavioral findings. This is in support of previous studies reporting such an effect on face processing with aging (Gunning-Dixon et al., 2003) . Nevertheless, although this result does contribute to a positivity hypothesis, it is unclear if this is a result of the level of processing that was needed for this task, which was easy (still photos), or due to other reasons as reported in the literature (e.g., motivational reasons – the positivity hypothesis in aging). In experiment 4, more comparisons will be made in order to examine Metaxas' (2015) suggestion that positivity in facial expression is a result of easiness-to-process a joyful expression.

Chapter V

Experiment 3: Humor discrimination electrophysiological counterparts in young and older adults

Summary of Experiment 3

Humor perception is an area not much studied by neuroscience. Cognitive Theories on humor are based on the resolution of an incongruity. This study aimed to explore the correlates of humor perception in young and older adults. Twenty one older adults and twenty two young adults matched in years of education and gender were presented with cartoons containing funny punchlines and cartoons without a funny element while simultaneously being measured by a 64 electrode EEG system. Behavioral results show that older adults had significantly lower accuracy to distinguish non funny cartoons. An EEG wave band analysis showed significant differences in delta band activity between funny and not funny items in the medial frontocentral electrodes and main effects for age group with older participants having higher delta wave activation as well as an interaction of age and type of stimuli in posterior electrode sites. Results contribute to the role of different brain regions in humor perception as well as the effects of aging in inhibitory processes of the brain.

When referring to humour processing in cognitive science literature, we usually speak of those elements in language or in visual stimuli not containing language such as a cartoon or a picture or video that contain an element of semantic ambiguity that is being resolved in an unexpectedly funny way. Theories on humour usually describe this process as a two-stage or three-stages. The two stage model, initially proposed by Sulz (Sulz, 1972), proposes that: first, an incongruity in the series of stimuli is encountered, followed by a second stage where the incongruity is resolved. Resolution is what is hypothesised to cause the humorous behavioural reaction. More recent versions of this model have included a third stage where the resolution brings up a pleasant emotional response (e.g. Tu et al., 2014) or a previous stage where the setup of the humorous scene is done before the incongruity detection (Attardo, 1997).

But this notion of semantic ambiguity is not considered adequate and comprehensive enough to account for all required elements for cognitive processing of humour. One critique to the stage model states that it doesn’t include the requirement for general social knowledge outside of the joke context (Channon, 2007) . Other critiques point out that not all humour is based on incongruity and even some humour does not contain incongruity at all (Forabosco, 2008). For the purpose of this study incongruity is the concept upon the experimental design was built and other kinds of humour were not examined.

Neurophysiological substrates of humor perception

What are considered the neural mechanisms underlying humor processing? In a review by wild (Wild, Rodden, Grodd, & Ruch, 2003), the areas that are most considered to be associated with humor perception include the Right frontal cortex, medial ventral prefrontal cortex, right and left posterior temporal regions. Frontal and temporal areas are very often reported (Amir, Biederman, Wang, & Xu, 2015) but also the left? temporoparietal junction which is considered an area where semantic appreciation and mentalizing takes place (Bekinschtein et al., 2011(Lombardo, Chakrabarti, Bullmore, & Baron-Cohen, 2011).

Incongruity is a concept tightly connected to language comprehension and pragmatics. It refers to the identification of an odd part in a series of stimuli, in this case a part that is later resolved in a humorous way. In respect to humor, the same neural substrates seem to support an incongruity element regardless of the stimulus presentation modality (i.e. verbal or pictorial/drawings) (Wang et al., 2017).

Incongruity was studied as a concept in detail in studies comparing incongruous endings of a joke with other endings of the same joke Studies with different cartoon endings (where the incongruity is not resolved) (Tu et al., 2014) as well as in studies where the stage model was examined and incongruity was resolved (Vaid et al., 2003). Neural circuits underlying the process of incongruity resolution have been examined in a small number of studies. These studies seem to contribute temporally to three different processes related to different topographies: first the detection of incongruity which appears as a negative ERP deflection around 400-500 msec (N400) and is located in mainly the left frontocentral regions of the brain (Bekinschtein, Davis, Rodd, & Owen, 2011), a positive deflection that is associated to incongruity resolution around 600-800 msec poststimulus and is located in mainly posterior regions (Du et al., 2013), and in some papers, a third component at 1000-2000 msec post-stimulus in posterior and anterior regions suggestive of the emotional appreciation of the stimulus after incongruity is resolved (Du et al., 2013; Tu et al., 2014).On the same late post-stimulus window, a slow wave (1-3.5 Hz) positive deflection in humorous cartoons and jokes has been identified which is also said to be relevant to the emotional appreciation of the stimuli (Feng et al., 2014), where a difference in frequency power between humorous and non-humorous videos was found in the frequency range of 28-32Hz (Ramaraju, Izzidien, & Roula, 2015).

Cognitive requirements of humor perception

Humor is a complex human behaviour that entails a number of mental skills. In order to understand many types of humour, theory of mind or mentalizing skills are needed (for a review on theory of mind its role to SC and aging see introduction). A very important part of humour mentioned in this review is social inferencing, a skill that is also considered a major part of what most types of humour entail. This connection is also what establishes humour perception as a SC measure. In a review paper on the cognitive substrates of humour (Channon, 2007), humour is connected closely to theory of mind as in many studies performance on humor tasks is related to the performance in mentalizing tasks. In a paper where the effects of aging on humor comprehension were measured, mentalistic and non mentalistic questions were made to participants on the tasks; the older group selected significantly fewer correct punchlines from alternatives than the other groups. They were also poorer at answering mentalistic questions (such as “What did the visitor think when he heard Martin speak”), but did not differ significantly for non-mentalistic questions (such as “Did Martin work in an office?”).

Humour perception and interpretation is heavily relied on intact language abilities which are largely maintained in older adulthood (Albert, 1981 Constantinidou et al., 2012; Giogkaraki et al., 2013; Uekermann, Channon, & Daum, 2006). Individuals with semantic impairment secondary to dementia or stroke, systematically demonstrate difficulties in producing and interpreting humor (Wild et al., 2003) In addition to language abilities, humor perception is very closely connected to executive functioning abilities. For example, it requires the deployment of inhibitory processes when having to inhibit a dominant meaning in order to identify and resolve the incongruity. Normal aging does affect several aspects of executive functioning and there is a link between language abilities and executive performance in older adults (Zelazo et al., 2004). , and this coincides with the prefrontal lobe dysfunction hypothesis in normal aging (West, 2000).

This study aims at adding knowledge to an emerging area of interest, that of humour perception and normal aging. The hypotheses are derived from two bodies of literature, a. the humour perception literature mainly involving the incongruity hypothesis and associated electrophysiological substrates, and b. the aging literature with a focus on executive language and language comprehension abilities. Two groups of participants, young and old, were asked to report if cartoons containing language were funny or not, while simultaneously being measured by EEG. The nature of this task will explain the point up to which compensation processes in brain aging are able to compensate for a task that involves language processing as well executive functioning up to some extent. It is expected that exposure to funny vs. non funny items will result in electrophysiological differences for both groups as measured by time frequency analysis. This will happen due to the element of incongruity resolution in funny items. Furthermore, although concerning the older adults group, differences between funny and not funny items on behavioural measures are not expected to be significant, due to the nature of the task requiring different cognitive functions, it is still expected that there will be significant differences on an electrophysiological level between groups.

Methods

Participants

Twenty one older participants (11 females, 10 males matched with twenty three young adults (11 females, 11 males) were included in this experiments. These participants were selected from a larger sample of volunteers. Left handed participants and participants with EEG signals containing large amounts of noise were excluded. Table 15 presents descriptives on the years of education for the two age groups.

Table 15. .Descriptives for years of education for the two age groups

Group	N	Min	Max	Mean (SD)
Older Participants	21	12	20	15.57 (2.171)
Younger Participants	23	12	20	15.33(2.244)

A t-test between groups on years of education was not significant, *t(42)*=.348, *p*=.729. All of them were generally healthy, without prior history of neurological or psychiatric problems. The sample size calculated to reach an effect size of 0.85 on repeated measures ANOVA between subjects, within subjects and interaction effects was minimum 16 participants per group (calculations were made with G-Power 3.1 software)

Procedure

All testing took place at the Center of Applied Neuroscience, University of Cyprus. Participants were recruited with a snowball sampling method. They were informed of the experimental procedures which included the cognitive assessment, the humour tasks, and the EEG measurements and they provided their written consent. The recommended standard procedures for the placement of the 64 electrode system cup were followed. Participants attended a brief training session to ensure that they are able to follow the experimental procedures of the study. All stimuli were computerized and special instructions for not moving were given in order to minimize noise.

Research Questions

Are there electrophysiological differences in time frequency analysis obtained by the processing of funny vs. non-funny items between the two groups?

Are older adults as accurate as younger adults in discriminating between funny vs. non-funny items?

Materials

Behavioral description

Seventy cartoons by a well-known Greek cartoonist (ΑΡΚΑΣ http://www.arkas.gr/) were selected from all his publications (permission was obtained by the cartoonist). Punch lines on the cartoons were presented gradually (5 seconds for the first lines and 3 seconds for the punchline which contained a maximum of 6 words). Cartoons having a humorous social inference (36 cartoons) as well as cartoons without a funny element (34 cartoons) of the same characters were presented and participants were asked to indicate if the cartoon was funny or not on a new screen (for a description of the piloting procedure refer to the general methods section). Reaction time and accuracy were measured as well as EEG recordings.

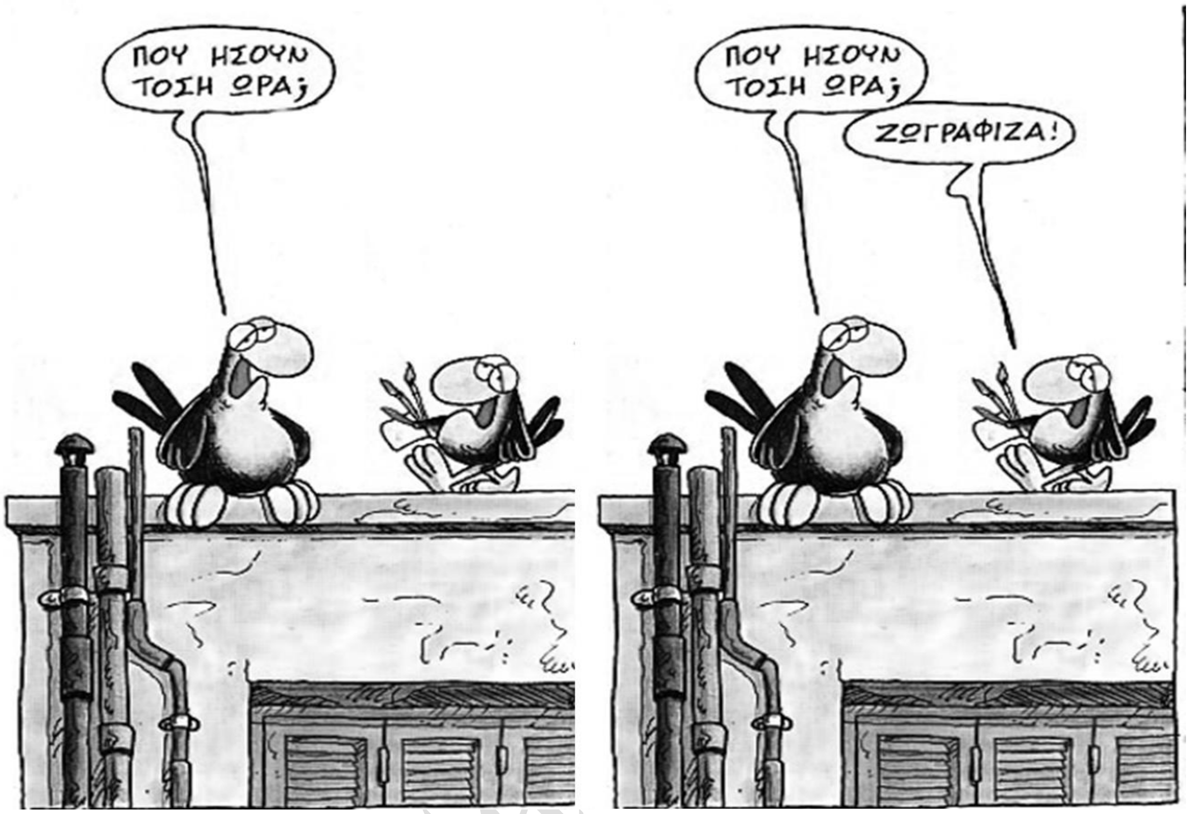


Fig 14. Example of a non-funny cartoon of sparrow father and son series

Fig 15. Example of a funny cartoon of the Sparrow father and son series

Tasks which were presented required a behavioral response limited to pressing one of two buttons on the computer keyboard. Behavioral measures were also collected (reaction time, accuracy).

Electrophysiological measurements

The data acquisition equipment was a high-density EEG/ERP recording system, an unshielded 64-channel BIOSEMI Active-Two. Samples were taken on a 256Hz sample rate with an online average reference.

Analysis (behavioral-electrophysiological)

Behavioral measurements were performed and analysed in the Statistical Package for the Social Sciences- IBM SPSS 24. The experimental procedure and presented 2 problems: Firstly, a definite time mark on when the punch line comprehension happened was not possible and significant amount of noise was present in the data due to a small number of trials. An ERP analysis was excluded as an option. Instead, a time frequency- wave band analysis during the period the sentence comprehension was expected to happen was performed (0-1500 msec).

EEG signal segments from the presentation of the funny element line to 2sec after were cleaned from artefacts due to external noise or muscle movements first by visual inspection for bad channels and then by software procedures. Artefact rejection and waveform averages were conducted with Brain Electrical Source Analysis – BESA 5.3 (www.besa.de) software. Averaged segments were imported into MATLAB where a Fast Fourier Transform analysis together with a Pwelch function calculation took place so that a single power measure for each wave band was extracted. The power rate on funny items and non-funny items for each participant was then entered SPSS where a repeated measures ANOVA was conducted with stimuli type (funny or not funny) as different (i.e. repeated) measurements and group (old and young) as independent (i.e. between) factors. A large activation in the delta band frequency (1.5-4Hz) was present in all participants in comparison to other frequencies. Differences between groups and type of stimuli were also present in delta band as well as an interactions between groups.

Results

Behavioral results

The mean accuracy is displayed in table 16 for the two groups on the funny and non-funny items.

Table 16. Mean accuracy (ACC) and reaction time (RT) for old and young group on funny and non-funny items

	Mean number of correct answers (out of 35) (SD)	
	Old	Young
	N=21	N=20
ACC funny items	24.10 (6.5)	25.04 (6.1)
RT funny items (in msec)	4002.10 (7583.5)	1850.30 (1031)
ACC NON funny items*	18.95 (7.4)	27.00 (4.7)
RT NON funny items	2375.62 (812.9)	1826.57 (801.6)

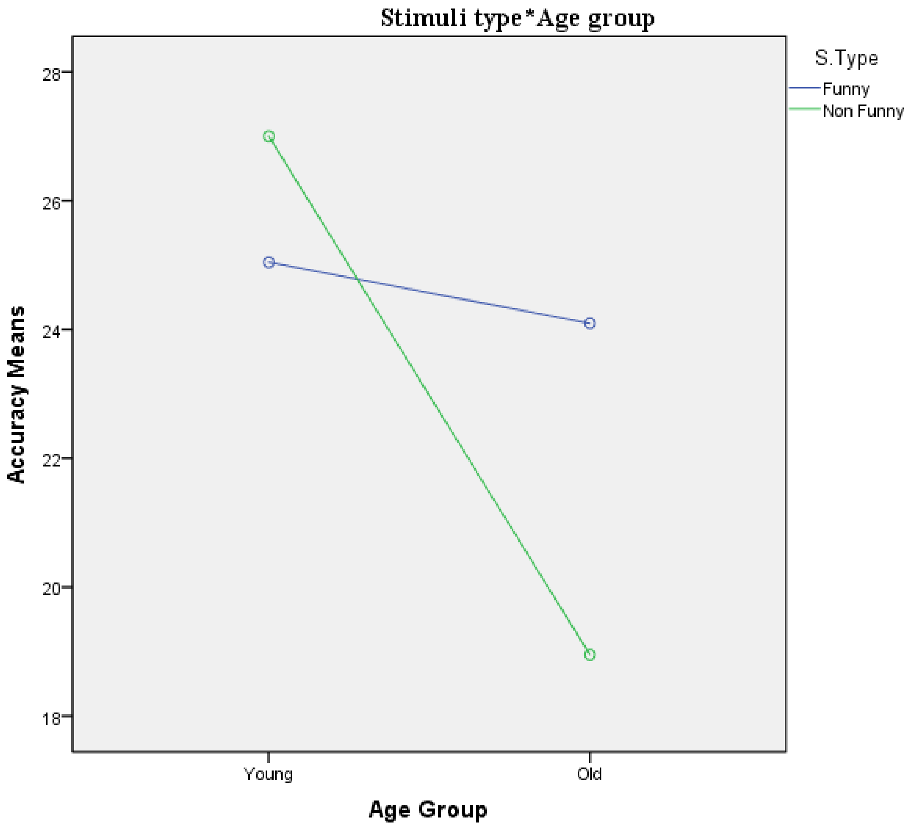
*$p<0,0001$

Behavioral scores were entered in a repeated measures ANOVA with group as the between subjects factor. Overall, older participants were equally accurate with younger participants in identifying funny or not funny items F(1,42)=1.02, p=0.318 . However, there was a significant interaction of type of funny element*group (F(1,42)=5.06 , p=0.030 η^2=.103). This interaction suggests that the two groups have different profiles in performance, with younger adults having much better accuracy for non-funny items as compared to older adults. Figure 17 is the graphic plot of the interaction effects. As it is shown in the figure, in non-funny items the two groups have an attenuated difference between means in accuracy.

To examine this further, a t –test between groups was performed only on non-funny items. Degrees of freedom reduced from 42 to 33 because Levene's test indicated unequal variances, F=9.01, p= 0.005, the difference between groups was significant t(33)=-4.27 , p=0.000 d=-1.4.

Reaction time was not considered a reliable measure due to its great variance between items. Therefore, reaction times were not included in the analysis.

Fig 16. Interaction between type (funny or not) by group (old and young) in behavioural measures



EEG analysis

A time frequency analysis was performed in the window of 0-1500 msec poststimulus. An attenuated activation on the delta wave band (0-4Hz) was observed. Power values of each channel within that frequency range were entered into a Two way repeated measures ANOVA with type (funny Vs not funny) as a within measures variable and group (old Vs young) as a between measures variable.

Table 17 p values on delta band power differences among conditions for channels with significant differences

Channels	**Funny Vs non Funny (type)**	**Young Vs Old (group)**	**Type by Group**
AF7	0.034		

AF3	0.003		
FC1	0.038		
FPz	0.027		
AF4	0.044		
AFz	0.005		
Fz	0.002		
F2	0.013		
F4	0.017		
F6	0.013		
FCz	0.014		
PO7		0.035	
Oz	0.015		0.026
T8		0.041	
P2		0.024	
P4			0.048
P10			0.055
PO8		0.015	
O2			0.044

Non funny items had significantly higher power in delta wave band on the first eleven channels displayed on the table. On posterior channels, older participants had significantly higher power in the delta wave band and in four cases the interaction between the two factors was also significant. As it is shown on table 17, channels resulting in significant differences between conditions seem to represent distinct electrode topographies that correspond to the condition. The difference in delta wave band power was apparent (frontal for the type condition and parietal-temporal for the group condition- see figure 17).

A factor analysis was used to identify different groups of channels that had significant differences either between age groups or between type of stimuli (funny Vs non funny) or an interaction of the two in delta band activation. Initial eigen values indicated that the first three factors explained 32%, 18%, and 9% of the variance in delta band frequency activation respectively. The three factor solution, which explained 60% of the variance, was preferred because of its theoretical support since conditions seemed to differentiate factors effectively.

Table 18. Factor loadings for channels with a significant p-value in the difference between age groups, between type of stimuli or an interaction of the two in delta band activation.

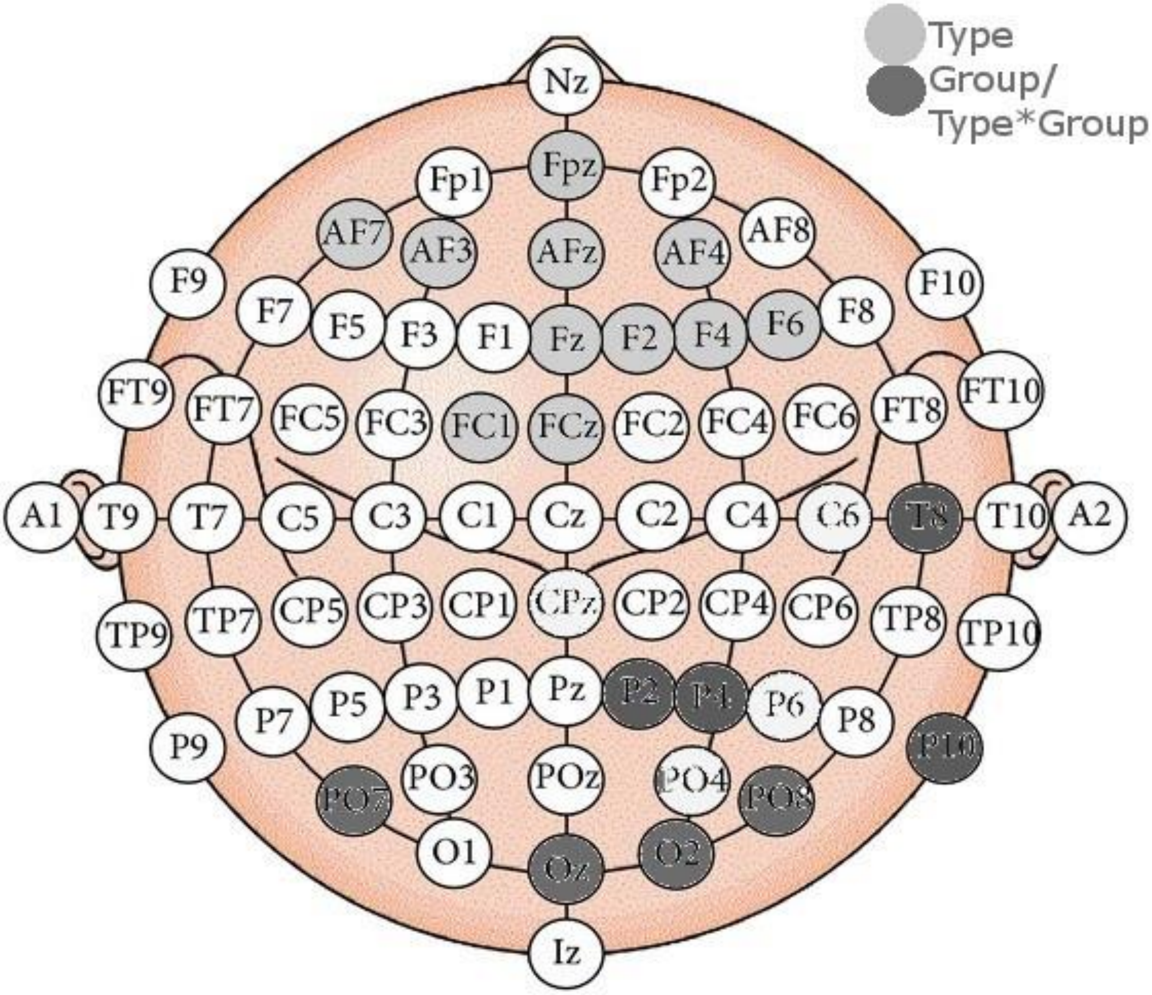
Channels	**Factor 1 (type of stimuli)**	**Factor 2**	**Factor 3**
AF7 funny	.625	-0.015	.439
Non funny	.782	-.217	-.254
AF3 funny	.806	-.259	.167
Non funny	.865	-.103	-.080
FC1 funny	.537	.183	.325
Non funny	.707	-.042	-.041
Fpz funny	.532	-.016	.259
Non funny	.723	.254	.121
AF4 funny	.797	-.174	-.085
Non funny	.911	-.076	-.105
AFz funny	.631	-.260	-.129
Non funny	.874	-.245	-.090
Fz funny	.506	.021	-.169
Non funny	.737	.009	-.147
F2 funny	.580	-.166	.361
Non funny	.892	-.214	-.096
F4 funny	.701	-.105	.092
Non funny	.772	.020	-.156
F6 funny	.711	.116	.182
Non funny	.840	-.018	.065
FCz funny	.663	-.155	-.200
Non funny	.801	-.217	-.254
PO7 funny	.249	.355	.402
Non funny	.215	.842	-.007
Oz funny	.189	.876	.103
Non funny	.197	.874	.092
T8 funny	.469	.595	.228
Non funny	.413	.765	-.145
P2 funny	.144	.193	-.578

Non funny	.044	.265	-.670
P4 funny	-.255	-.060	.676
Non funny	-.182	.019	.614
P10 funny	.206	.873	.204
Non funny	.129	.700	.025
PO8 funny	.055	.824	-.322
Non funny	.056	.750	-.349
O2 funny	-.187	.288	.664
Non funny	-.220	.477	-.229

(Factor 1 explains 31.99% of the variance while factor 2 explains 18.22% of the variance and factor 3 explains 9.43% of the variance)

Factor loadings differentiated effectively the conditions of the experiment. Factor 1 grouped together all electrode sites that had significant differences on delta band frequency activation on funny vs non funny items. Factors 2 and 3 grouped together all electrode sites that had significant differences in delta band activation frequency in different age groups or an interaction between age group and type of stimuli. Different groupings also have distinct topographies on electrode sites as it is shown on figure 16.

Fig 17. Topographies of electrodes with significant p values for the two different factors



Factor 1 is located in frontocentral electrode sites, bilaterally. Factors 2 and 3 are located primarily in right posterior electrode sites with some representation in the left posterior area.

Discussion

Two groups of participants, old and young matched in gender and years of education were presented with an experimental task where they were asked to decide if cartoons containing captions were funny or not. Accuracy measures and EEG measures were collected simultaneously. Behavioral results do not show significant differences between conditions on accuracy or reaction time. A significant interaction between conditions was found, where in non-funny items the difference between groups was significant favouring younger participants. A time frequency analysis revealed differences between conditions in the delta waves power (0-4Hz) in a number of electrodes. Delta band power was higher in non-funny items for some channels, and in other channels it was higher in older people or had a significant interaction between conditions. A factor analysis on the channels that showed significant power differences showed they can be grouped to at least two components by condition (type, group). Furthermore, the locations of electrodes are pointing out at distinct electrode sites, namely a bilateral medial frontal area and a right posterior electrode site region with some representation in the left posterior area as well.

This study used the differences in the power spectrum of delta band (0-4Hz) as a measure. The study of Delta band waves was not extensively studied with individuals who are engaged in a cognitively rigorous task. The present study makes a contribution in this emerging body of literature Studies examining this wave spectrum usually concern deep sleep or animal studies. Despite this, a few studies have investigated the role of delta oscillations in cognition and specifically in attentional processes. Delta waves are reported to be implicated in attention, salience detection, and subliminal perception (Knyazev, 2012). Other studies support that delta waves are connected with the activity of motivational systems and participate in salience detection, so that an increased slow-wave activity can be associated with cognitive declines and a lack of inhibitory control (Knyazev, 2007). The relation of delta wave increase with a lack of inhibition is also reported in several other studies that Harmony (2013) reports in a review on delta activity and attention. They propose that sustained delta oscillations inhibit interferences that may affect the performance of mental tasks, possibly by modulating the activity of those networks that should be inactive to accomplish the task and are associated with functional cortical differentiation, or inhibition of the sensory afferences that interfere with internal concentration. These inhibitory oscillations would modulate the activity of those networks that should be inactive to accomplish the task. Another study focuses in the appearance of delta waves when there is an increase in attention to an internal process (T Harmony et al., 1996).

On a paper on visual perception Helfrich et at (2017) support that delta activity on visual perception stems from the prefrontal lobe and controls alpha activity selectively facilitating visual perception. (Helfrich, Huang, Wilson, & Knight, 2017). In the current study, a delta band power was calculated in a large time window (0-1500msec), thus incorporating all processes that are described in literature. It is possible that in earlier temporal windows (before 400msec poststimulus), the delta difference between groups can be explained by the brain’s attempt to modulate visual perception, but in line with the prefrontal lobe aging hypothesis favouring younger people.

Although this experiment design didn't have the perspective of a clear temporal windows distinction (the "comprehension of the punchline" time trigger was not possible to be strictly identified), some of the results concerning the distinct components according to conditions and electrode sites can be an indication of different processes going about in humour perception. As reported in the literature, in early stages of humour perception (400-500msec), very often a medial frontal and prefrontal area is involved in the incongruity identification stage (Du et al., 2013), which coincide with electrode site areas that represent channels which presented significant differences concerning the type of stimuli (non-funny items vs. funny).

Slow wave activation has also been reported in later stages of humour perception (Feng et al., 2014), and temporally different processes involving posterior regions such as the temporoparietal junction. In this study, in another cluster of electrodes differences were identified between old and young participants in posterior electrode sites. This is related to the time window where attention needs to modulate cognition and EF become more necessary, resulting in aging effects being more apparent.

Delta wave band differences have been related to an inability of inhibitory processes. It has been reported previously in the literature that aging affects inhibitory processes to a significant degree (Dustman, LaMarche, Cohn, Shearer, & Talone, 1985; Hasher et al., 2001; von Hippel, 2007). It is possible that the significant difference in delta waves power between the old and young participants group may be attributed to such a lack of inhibitory control with aging.

Can this difference in some channels and topographies in older people as well as in behavioural results be attributed to different findings concerning theory of mind tasks or language tasks in aging? Older people seem to be performing equally to young people in funny items, but do have a difference in distinguishing non funny items as well as presenting a higher delta band activation in posterior electrode sites. Does this have to do with the systems lack of connecting information, a function often attributed to the temporoparietal junction (Saxe, 2006) ? Or can it be attributed to a difficulty to mentalize and resolve the incongruity involved in humour perception (Uekermann, Channon, & Daum, 2006)? Further connections to SC, aging and their components will be made in experiment four. Further studies should aim at establishing a temporal picture of the processes happening in humour perception and aging.

Chapter VI

Experiment 4: SC in normal aging: Relationships between behavioural and electrophysiological measures

Summary of Experiment 4

SC in normal aging is mainly based on a 'cognitive functions compensation and a frontal lobe decline' hypothesis. Previous experiments in this study established that normal aging results in decline in certain aspects of EF that also affect components of SC. In this experiment, twenty-eight older participants and twenty-seven younger participants matched in gender and educational level were tested in a series of neurocognitive and SC tests and in two experimental tasks while EEG measures were recorded. Behavioural and electrophysiological measures were analysed indicating that the positivity effect in facial expression recognition is more related to still vs. dynamic stimuli, humor discrimination task performance is related to EF performance and overall SC performance is related to executive function performance. Results contribute to answering questions on how far can compensation processes in brain aging recover SC functions, and to the relationship of SC with executive functioning.

The daily demands of SC tasks during normal conversation involve timed responses and intact speed of processing along with other neurocognitive abilities such as working memory and aspects of executive functioning (emotional inhibition, cognitive, shift, and implementation of strategies). Research has demonstrated that these related abilities can be affected by healthy aging and can cause reductions in SC performance. SC deficits associated with aging gradually add up to a social skills decline in older adults (von Hippel, 2007). It is therefore important to examine the intersections of SC with neurocognition and determine which aspects of EF are relevant to SC components (Salthouse, 2000; West, 2000).

As previously mentioned in this dissertation, older adults are able to maintain certain cognitive-linguistic abilities, including semantic knowledge and receptive vocabulary. These abilities are associated with crystalized intelligence or 'hold' tasks and while they are affected by their level of education, they are resistive to the effects of aging. It has been hypothesized that some aspects of cognition are compensated through aging. Older adults use other areas of the brain, mainly the frontal lobes in different kinds of tasks. In some tasks they are able to even reach a similar performance as younger adults in tasks that are considered to be examining crystallised intelligence, such as vocabulary tests or language tests that are not time limited with simple stimuli (Albert, 1981). This compensatory mechanisms of the brain are noticed also in brain activation, where other brain areas, mainly the frontal lobes are more activated in older adults , even in tasks that are not processed by the frontal lobes in younger adults, a result that was also implied in experiment 2 of this study (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Cappell, 2008).

In a study of SC in normal aging, Metaxas (2015) has found that executive functioning performance does affect SC performance in the emotion recognition tasks but not in tasks related to language components such as the proverbs test, a test that is used also in this study. He also noted that what is considered as the positivity hypothesis in aging, a hypothesis mainly proposed to describe a series of behaviors in older adults who are considered to be focusing on positive experiences due to motivational reasons (Mather & Carstensen, 2005), does not seem to be the case in facial expression recognition. Alternatively, he proposes that positive facial expressions enjoy a privilege in processing as long as the stimuli remains simple. His findings support the idea that dynamic stimuli do not show the same pattern of results.

Prior to experiment 4, three experiments were conducted incorporating behavioural and electrophysiological measures of neurocognition and SC. In experiment 1, age groups were compared on behavioural measures. Results showed that older people perform significantly lower in tasks of memory (verbal and spatial memory), and in executive functioning tasks such as complex visual processing and visual-spatial organization, visual scanning, mental flexibility and non-verbal symbolic processing and in emotional recognition measures with animated stimuli. Performance in language measures as well as emotion recognition performance of static images was not significantly different in age groups.

In experiment 2 where participants were tested on a facial expression recognition paradigm, results showed that joyful faces were easier to process by young and older people as measured by accuracy, but also as measured by amplitude even in early stages of processing such as 150-200 msec poststimulus. Furthermore, in both behavioral and electrophysiological measures, older people had a greater difficulty in processing all-but-joyful facial expressions, thus verifying the original hypothesis. The N170 component appeared in parietal-occipital electrode sites where significant differences were also found in all subjects in processing joyful vs all-but-joyful emotional expressions. Significantly higher amplitudes were observed on the 150-200-time window in older people over frontal and central electrodes.

In experiment 3 where participants performed a humor discrimination task, bbehavioral results did not show significant differences between conditions (funny-non funny, young-old) on accuracy or reaction time but a significant interaction between conditions was found where in non-funny items the difference between groups was significantly favouring younger participants. A time frequency analysis revealed differences between conditions in the delta waves power (0-4Hz) in a number of electrodes. Delta band power was higher in non-funny items for some channels, and in other channels it was higher in older people or resulted in a significant interaction between conditions. A factor analysis on the channels that showed significant power differences showed they can be grouped into at least two components by condition (type and group), and the locations of electrodes are pointing out at distinct electrode sites, namely a medial frontal area and a right posterior electrode site region. Below, you can see a schematic representation of all results of this experiment.

Table 19. Summary of all results

	Significant differences between age groups	
	Behavioral results	Electrophysiological results
Memory tests	YES	NA
Executive Functioning tests	YES	NA
Emotion recognition dynamic stimuli	YES	NA
Emotion recognition still stimuli joyful images	NO	NO
Emotion recognition still stimuli all-but-joyful images	YES	YES (in visual processing electrode sites)
Humor discrimination funny items	NO	YES (in language processing areas)
Humor discrimination non funny items	YES	YES (in language processing electrode sites)

This experiment aims at examining associations between behavioral and electrophysiological measures so that a more comprehensive set of conclusions on how aging affects SC and neurocognition can be drawn. Performance on SC measures was compared to cognitive test results in order to determine relationships that are relevant to the age-induced cognitive decline on SC and the level of interdependence between cognition and SC in aging.

For older adults, it has been previously reported in the literature that social skills may either not deteriorate due to “social wisdom” (in the case of Theory of Mind, see Moran, 2013) or deteriorate as a result of a decline in EF (von Hippel, 2007). It was expected that older adults would exhibit a corresponding decline in executive function measurements and SC measurements. Furthermore it was expected that SC performance would be lower for older adults in emotion recognition tasks, especially in tasks that involved dynamic stimuli, as Metaxas (2015) reported. It was also expected that performance in executive functioning would be related to SC tests performance. It is yet to be seen if language tests would be related to performance in the humor discrimination task as measured by behavioral (accuracy and reaction time) and electrophysiological indices (peak amplitude, latency and delta frequency) for both groups.

Methods

Participants

Twenty-eight older adults (mean age M= 68,46 min 65 max79,15 females, 13 males) were matched with twenty-seven young adults (mean age M= 33,68 min 28 max 42, 14 females, 13 males) on gender and years of education.

For this experiment MANOVAS and Canonical Correlations were used. Power analysis for a MANOVA with two levels and three dependent variables was conducted in G-Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.80 and a large effect size f=0.40. Based on these assumptions the desired sample size is 20. Concerning a canonical correlation, for a large effect size p=.50 for a two tailed alpha of .05 and power =.80 it was determined that a sample size of 26 is required.

Procedure

Participants were tested at the Center for Applied Neuroscience in Central Campus, University of Cyprus. Participants were informed of the procedure (concerning cognitive assessment and EEG measurement) and signed a consent form.

Experimental setting procedures for the ERP: The equipment for the ERP measurements is located in a specially designed laboratory room at the Center of Applied Neuroscience, University of Cyprus. The recommended standard procedures for the placement of the

64 electrode system cup were followed. The participants participated in a brief training session to ensure that they are able to follow the experimental procedures of the study. All stimuli were computerized and special instructions were given in order to minimize noise. For further details on procedure please refer to chapter II general methods section.

Research Questions

Is there a difference between groups in facial recognition performance when processing dynamic and non-dynamic stimuli as measured by electrophysiological and behavioral indices?

Is performance on humor discrimination measures and other SC tasks related to language measures and to EF measures across groups?

Materials

A series of neurocognitive test measuring executive functioning, memory and language was administered as well as a SC battery. Two experimental tasks, namely a facial expression recognition task as well as a humor discrimination task were also administered to the participants with simultaneous EEG recordings. (For description of the tests and experimental tasks refer to the general methods section)

Analyses

Data were collected from all experimental procedures described prior to this experiment. All data extracted from other experiments were entered IBM SPSS statistics 25 where MANOVA in on case followed up by a K-cluster analysis to establish what variables separate better the two groups , and canonical correlations to establish correlations between general variables such as executive functions and social cognition were performed. All data used were examined and found adequate for normality.

Results

SC and aging

To examine if SC performance is different between age groups the SC measures were put together from the two categories: emotion recognition, social inference. Age group performance on all measures was entered into a MANOVA with test scores as dependent factors and age group as a fixed factor.

Table 20. Descriptives for emotion recognition measures

Measure	**Group Mean (SD)**	
	Older	Younger
CAM faces	30.11 (5.050)	35.11 (4.484)
CAM voice	31.32 (3.465)	34.00 (2.287)
Speed movies	56.69 (8.049)	70.35 (5.433)
N170 amplitudes joyful	-.91 (1,99)	-2.8 (2.3)
Face recognition all-but-joyful accuracy	80.08 (11.957)	88.86 (5.783)

Table 21.Descriptives on social inference measures in the two age groups

Measure	**Group Mean (SD)**	
	Older	Younger
Humor Discrimination accuracy on non-funny items	18.95 (7.386)	27.00 (4.661)
Humor discrimination delta wave band on posterior cluster electrodes non funny items	10.17 (11.63)	3.21(3.79)

All measures had significant differences in individual ANOVAS (refer to experiment 1). All SC measures were entered a MANOVA where there was a statistically significant effect of age group on performance on SC measures F (11, 21) = 5.848, $p < .0001$; Wilk's Λ = 0.754, η^2=0.754

Language, aging and SC

Language measures were entered in a MANOVA to examine if language measures performance was different according to age group

Table 22 Descriptives on language measures in age groups

	Groups means (SD)	
	Older	Younger
Proverbs test	23.46 (2.996)	22.96 (3.075)
PPVT	28.43 (2.150)	26.89 (4.228)

There was not a significant difference between age groups in language test performance *F (2, 48)* = 1.391, *p*>0.05; *Wilk's Λ* = 0.945

A bivariate correlational matrix between the humor recognition variables and the language variables showed no significant correlations between variables belonging to the humor recognition with language measures. A canonical correlation also revealed no significant canonical function.

SC and EF

To test whether EF measures were related to the SC measures a set of two different canonical correlations were performed. First, emotion recognition measures relationship with executive function measures was explored.

A canonical function that is significant emerged with *r*=.909, *p*=0.006. Emotional recognition variables that had the highest coefficients were CAM Faces (1.01), Speed movies (.289) and emotional faces accuracy in joyful faces in a negative way (-.392). Executive functioning variables that had the highest coefficients were Towers of Hanoi time of completion (-.594), Rey complex figure copy (.449) and symbol digits test (.554). Other canonical functions were not significant.

Following that, a canonical correlation was also performed to explore the relationship of executive functioning measures with humor discrimination variables. A canonical function that is significant emerged with *r*=.843 , *p<0.0001*. Behavioral accuracy had a higher coefficient, accuracy on non-funny items (-.848), accuracy on funny items (-.635) and on the EF measures the symbol digit test (-.580) and the trails B (.395). Relations between humor appreciation and the trails test were found also elsewhere (Shammi & Stuss, 1999).

The positivity hypothesis

Special measures to assess the positivity hypothesis were combined in two separate MANOVAS with age group as a between subject variable.

Table 23.Descriptives on non-positive measures

Measure	Group Mean (SD)	
	Older	Younger
Speed movies errors on all but joy	37.88 (6.96)	24.81(5.11)
Emotion recognition accuracy all but joy	80.08 (11.957)	88.86 (5.783)
N170 amplitude on all but joy	-.72(1.75)	-1.67(1.19)

On non-joyful facial expressions recognition measures, older participants had significantly lower performance *F(3,33)*=16.669 *p<0.0001*; *Wilk's Λ* = .405

Table 24.Descriptives on positive measures

Measure	Group Mean (SD)	
	Older	Younger
Speed movies errors on joy	1.42 (1.88)	.85 (.925)
Emotion recognition accuracy joy	89.67 (8.045)	93.41 (3.892)
N170 amplitude on joyful	-,91 (1,99)	-2.8 (2.3)

On joyful facial expressions recognition measures, older participants also had significantly lower performance *F(3,33)*=16.669 *p<0.0001*; *Wilk's Λ* = .405 although on separate ANOVAS (refer to experiment 1) still images measures did not present significant differences. For the purposes of this analysis the still measures used were the measures from the experimental facial expression procedure and dynamic measures were CAM faces and voice test as well as the speed movies test.

To further examine this hypothesis of still vs. dynamic stimuli as Metaxas (2015) suggested, a k-means clustering procedure was followed to examine which category better separates age groups. The confusion matrices of the clusters created for still and dynamic stimuli are presented below

Table 25: still stimuli clusters

	1	**2**
Young	18	0
Old	12	9

Table 26: dynamic stimuli clusters

	1	**2**
Young	1	25
Old	18	8

As we can see from the matrices, dynamic stimuli are much more precise in differentiating the two age groups.

Discussion

This study aimed at combining the results of three other studies to reach conclusions regarding the basic hypotheses concerned in literature of SC and normal aging. Two groups of participants matched in gender and educational level were tested in a series of neuropsychological and SC tests as well as two experimental procedures (emotion recognition in still faces, humour perception), the latter with simultaneous EEG recordings. Analyses were made to establish the relationship between these measures and their ability to distinguish age groups. Results show that older participants perform significantly different than young participants in measures of emotion recognition and in all SC and executive functioning measures. Differences in language measures were not significant. Performance yields a positivity effect for static measures. However, positivity effects disappear during dynamic measures, similar to Metaxas (2015) findings.

Humour perception performance did not correlate with language performance on semantic knowledge and proverbs test. However, humor perception performance correlated significantly with executive functioning measures measuring inhibition and control. This finding clearly demonstrates that while humour perception requires an intact language system, it is more related to executive functioning. Performance on all SC measures correlated significantly with executive functioning demonstrating the strong bond between the two sets of complex processes.

The results of this make significant contributions to our understanding of the interplay between important cognitive functions such as SC, language, and executive functioning and the effects of healthy aging. Specifically, the study demonstrated that both SC and executive functioning abilities as clusters decline with age. In contrast, language abilities as measured by the vocabulary test and the proverbs test as well as the humor discrimination on funny items remained intact. Furthermore, performance on executive functioning predicted performance on SC measures as already described in the literature (von Hippel, 2007). The current findings expand the existing literature by providing insights concerning the limits of compensational mechanisms in normal aging. They also enrich the existing literature by providing data on different aspects of SC and their relationship with EF and aging. Analyses on the humor discrimination task used, give support to the theoretical connection between humor perception and executive functioning (Shammi & Stuss, 1999). Furthermore, the results shed light on the declines appearing in SC modules such as emotion recognition. In emotional recognition Metaxas' (2015) suggestion on the separation of emotional recognition to still and dynamic where the positivity effect disappears, finds support. Furthermore, due to the different data sources and sample used in this study a proposal on an explanation for this observation is made. This discussion continues in the next section, as general discussion.

Chapter VII

General Discussion

. This study’s main aim was to begin a systematic research program in order to bridge the research gap between behavioral and electrophysiological components of SC in normal aging. Four experiments were designed to systematically explore different behavioral, cognitive, and neurophysiological underpinnings of SC. In the first three experiments, electrophysiological and behavioral data collected on neurocognition and SC functions were analyzed and explained in the context of normal aging. In the fourth experiment, data from the three experiments were synthesized in an attempt to draw conclusions and advance the current State-of-the-Art in SC theory and aging.

The aim of Experiment 1 was to determine whether aging affects neuropsychological functions or SC measures. Results showed that older people perform significantly lower in tasks involving verbal and spatial memory, in spatial construction ability, visual scanning and tracing—executive function abilities—and in emotional recognition measures with dynamic stimuli. However, performance on language measures and on still image emotion recognition was not significantly different across age groups. The results of this experiment contribute towards a SC model in aging which supports the notion that some neurocognitive and social cognitive abilities are stable across time whereas some other aspects requiring dynamic and online processing abilities are affected by aging. This was further examined in experiment 4.

The aim of Experiment 2 was to test basic hypotheses on aging and SC by measuring electrophysiological components of facial emotional expression processing. Results showed that joyful faces were easier to process by both younger and older people as measured by accuracy and ERP amplitude. This was true even in the early stages of processing (150-200 msec poststimulus, or N170) with regards to ERP peak amplitude.

However, the experiment resulted in group differences during processing of all-but-joyful facial expressions”. First of all, older adults demonstrated significantly decreased accuracy in the behavioral measures. Secondly, the N170 component appeared in parietal-occipital electrode sites where significant differences were also found in all subject data when processing joyful vs all-but-joyful emotional expressions, with some sites showing this type of stimuli difference only in older adults. Finally, significantly higher amplitudes were observed in the 150-200msec time window in older people via frontal and central electrodes for all types of stimuli. The findings of this study gave further insights into emotional expression processing in aging, indicating that aging differences can appear in early stages of stimulus processing.

In Experiment 3 participants were presented with an experimental task on humor perception where they were asked to decide if cartoons with language elements were funny or not while simultaneously being measured by EEG. Behavioral results were not significantly different between conditions in terms of accuracy or reaction time, although older participants had a significantly greater reaction to non-funny stimuli. A time frequency analysis revealed differences between conditions in the delta wave power band (0-4Hz) in a number of electrodes. Delta wave band power was higher in non-funny items for frontal channels; in posterior channels it was higher in older people or had a significant interaction between conditions. A factor analysis of the channels with significant power differences also showed that channels can be grouped into at least two components by condition (type, group), and that the locations of electrodes point to distinct electrode sites—a medial frontal area where electrodes differed according to the type of stimuli, and a right posterior electrode site region where electrodes differed according to age group. Results can be used to identify humour processing decline and the interaction with compensational mechanisms in aging.

Experiment 4 aimed at integrating the results of the three previous studies in order to draw conclusions about basic hypotheses on SC and normal aging put forth by the literature. Analyses were conducted to establish connectivity between most of the measures used in the study and their ability to distinguish age groups. Results showed that older participants have much more difficulty than younger participants in measures of emotion recognition and in all SC and executive functioning measures. Differences between age groups in language measures, however, were not as significant, as the literature suggests. Positivity measures performance did vary according to age group, but as Metaxas (2015) has noted, when emotion recognition measures are dynamic, the positivity effect disappears. Beyond Metaxas' findings emotion recognition does seem to be compensated for in aging where stimulus processing demand is limited. Moreover, humor perception task performance did not correlate with language measures performance, but it did correlate significantly with executive functioning measures, thus supporting the hypothesis that humor perception is not only a language measure but also a cognitive measure. Finally, performance on SC measures was strongly correlated with performance on executive functioning tasks.

The present study proposed a multidimensional theoretical model of SC with Emotion Processing and Social Inference serving as key components (see Figure 1 in Chapter I). Age and EF would affect directly and indirectly SC abilities. The present study provides support to the above conceptual framework. Specifically, age was found to affect both EF and SC. In turn, EF, seem to affect social cognition directly and through emotion processing and the social inference task used in this study.

The results of all the experiments taken together deepen our understanding of key areas of SC explored in this study. The following sections synthesize the results in order to advance the current State-of-the-Art in emotion recognition, humor perception and SC in normal aging.

Emotion recognition and SC in aging

Previous studies used facial expression to draw conclusions about the electrophysiological components of emotion processing as well as to add to the theoretical framework of SC as a whole (Adolphs, 2001). However, this study is one of the few to look at emotional expression recognition in older adults and its implications for SC in aging by replicating the finding that emotional processing happens in different areas of the brain for the aged (Gunning-Dixon et al., 2003). An important new contribution of the present study is the finding that the N170 is an adequate measure for distinguishing differences in emotional expression processing between age groups. An alternative explanation could be that the decline in emotion recognition performance could be attributed in part to EF decline associated with normal aging (especially in tasks with high demands in speed of processing). Future research in this area should control for cognitive performance in order to ensure that general cognitive abilities do not cause the emotion recognition decline observed in the current study.

Another important contribution of the present study is that it determines the moment when emotional expression starts to be processed. Studies on how emotional expression modulates the N170 component have so far given contradictory results. Rellecke et al. (2013) suggested that this difference among studies is related to methodological issues, and specifically the reference used with studies using the mastoids reference showing no results and others using the average reference showing modulation by emotional expression. In the present study, the average reference was used, demonstrating a modulation by type of expression. It is important to note that the electrophysiological data were replicated by the behavioral results of this study, revealing that older adults were more accurate for funny items than non-funny items, whereas for the younger group this difference wasn’t observed. Future studies should examine whether the average reference is a more accurate reference for the measure of the N170, while crosschecking results with established later electrophysiological measures for face processing that can distinguish between age groups.

Later components are also reported in the emotional expression processing literature. A positivity around 270 msec as well as a N400 have been reported to appear in paradigms with emotional faces stimuli (Sato et al., 2001). In the current study, data seems to indicate a late positivity peak as appears on waveforms, but quantitative data were not extracted for examination in relation to the variables. Further studies should focus on examining these late components in the same or a similar paradigm and population within a theoretical framework for the modulation of attentional processes involving emotional expression.

Findings from the study reveal two processing areas, a frontal area (age groups differences) and a parietal-occipital area (type of stimuli differences). The differences between groups in the frontal area may be explained by the compensation hypothesis in aging and the prefrontal hypothesis (Reuter-Lorenz & Cappell, 2008), which argue that older people use the frontal areas of the brain to process emotional expression in faces, whereas younger people use more visual areas (Gunning-Dixon et al., 2003). The effects on the posterior regions of the brain provide evidence of the integrative role of these regions and the important role they play in SC by combining and integrating emotional stimuli (e.g. Saxe, 2006). The parietal-occipital region was also found to be more activated across groups in all-but-joyful emotional processing, and in older adults when presented with both funny and non-funny humor recognition items. In the first case, increased activation could represent initial visual processing, whereas in the second case it could represent another processing timeframe, i.e. synthesis of different sensory input and the difficulty older participants in combining socially relevant information in such a complex task.

Behavioral and electrophysiological data from this study indicate that joyful facial expressions are easier to process by older people. Metaxas (2015) argues that this difference disappears when the stimuli become more complex, suggesting that the original difference doesn’t stem from a motivational background related to positivity in late adulthood, but rather from a processing privilege due to the developmental importance of the stimuli. Furthermore, the differences in performance favoring still stimuli, even with a sample matched in years of education (Metaxas did not control for education), reinforce the hypothesis that compensation mechanisms triggered by aging are a more probable explanation for this phenomenon. Compensatory mechanisms were also observed in the results of the humor discrimination experiment.

Humor perception and SC in aging

This study contributes significantly to our understanding of humor processing and normal aging. Specifically, it demonstrates that compensatory mechanisms in normal aging, as measured by electrophysiological indices, modulate humor perception. Furthermore, the study provides evidence on how delta waves could be used to measure differences between age groups in processing humorous and non-humorous depictions, which clearly require different levels of attentional resources, thus engaging EF to a higher degree. Finally, as it is a study that uses cartoons with language elements, this study also adds to the literature of humor perception, which has so far only analyzed joke comprehension in terms of language alone and cartoons that didn't use language. The results of this study show that a combination of the two triggers compensational mechanisms and that, although brain activation shows differences between groups, behavioral performance remains the same for cartoons that use funny vs non-funny stimuli.

The incongruity resolution model supported by humor literature is partially supported by this study. Although the delta wave band difference in processing humorous and non-humorous cartoons indicates that the resolution of incongruity is an indication of humor identification, studies still need to elaborate on how delta wave indication is able to distinguish between the different stages in incongruity resolution (incongruity identification, incongruity resolution, and emotional appreciation of the humorous stimuli). Studies link the appearance of delta waves to the N400 (Thalía Harmony, 2013). Further studies should focus on the appearance of N400 and delta wave activation in stimuli containing humorous elements and stimuli where incongruity isn't resolved. The topographies of these components is also a subject that needs further study. For instance, this study didn't use an imaging method to locate exact data on topographies. According to the stage model used by previous studies, these topographies have a temporal course that can't be identified due to the large time window of the analysis. A paradigm that can make very accurate time marks on humor perception stages in combination with different imaging techniques, such as an integration of EEG or FMRI, could lead to an accurate description of topographies in humor perception.

This study aimed to answer a very specific question: whether the aging brain can compensate for different types of humor processing demands or characteristics. Previous studies on static language knowledge (Gunter et al., 1995), as well as some studies on Theory of Mind (Duval, Piolino, Bejanin, Eustache, & Desgranges, 2011) -both cognitive areas this study deals with-supported the notion that the decline in these abilities can be compensated for in normal aging. Our study results showed that most abilities used in humor processing are still easily handled by older adults when they encountered a funny element. However, when they encountered a non-funny element, their ability to recognize it was impaired, resulting in a drop in accuracy. This result is reinforced by electrophysiological results that show reduced delta activation between groups in electrode locations where the combining of information during SC processing is reported to happen, such as the temporoparietal junction (Saxe, 2006).

Finally, the present findings on humor perception enrich our understanding of the relationship between SC and general cognition in normal aging. Despite the fact that humor is an asset in aging that activates mentalizing and language skills, the task used in this study was mostly correlated with performance in executive functioning tasks. As such, this could be interpreted as a task that placed significant demands in the ability of older adults to compensate for skills that are vulnerable to cognitive aging (i.e. EF).

Aging and brain functions

The literature on aging suggests that the prefrontal lobe is an area vulnerable to biological aging (West, 2000). This assertion has been verified in imaging studies and in studies using neuropsychological measures (Reuter-Lorenz, 2002). Neuropsychological functions like EF are mostly attributed to the prefrontal lobe cortical and subcortical networks, and those structures are the first to show signs of deterioration (Zelazo et al., 2004). In the present study, older participants performed significantly lower on executive functioning measures The prefrontal lobe is also involved in basic SC functions like mirroring, which is the foundation of mentalizing abilities (Saxe, 2006). Aspects of mentalizing examined in this study showed that although some of these abilities can be effectively compensated in healthy older adults, mentalizing deteriorates when the experimental paradigm becomes more complex.

In the present study, frontal lobe activation as shown by performance on executive functioning tests and electrophysiological measures seemed to be significantly stronger for older adults, suggesting that compensation mechanisms are triggered to maintain performance, something that is apparent in tasks that entail language processing, such as responding to proverbs (proverbs test) and humor (humor perception test). The increased activation is thought to be a compensatory mechanism in order to manage more difficult tasks since the behavioral performance on these tasks was similar between young and older subjects. This finding clarifies the fact that performance stability in certain measures in older adults—especially educated adults like the ones studied—is connected to compensatory mechanisms and not to a lack of declines.

Simple Theory of Mind abilities are considered to also be compensated for in aging. Studies report that while older people are able to compensate for their performance in first order ToM tasks and do not show differences, in second order, or more complex ToM tasks, the difference becomes apparent when engagement of attention and working memory are measured (Duval et al., 2011). Although in this study no direct measure of ToM was used, the humor perception task involved at least a social inference-making component as well as a mentalizing component. Our results replicate findings (Uekermann et al., 2006) that show that older people process funny cartoons more effectively than non-funny cartoons and that basic humor perception can be compensated for, at least by older educated adults.

The aging brain's ability to compensate for diminished functions is closely linked to education and cumulative life experiences that form the theoretical construct of "cognitive reserve" (Whalley et al., 2004). In this study, participants were highly educated and matched in terms of education with controls. The results demonstrate the electrophysiological underpinnings of this effect.

SC in aging

Because SC is linked to frontal lobe functioning, it is expected to be influenced to a great degree by aging, although there are areas of SC that aren't as affected as others. In this study, we have shown that when all SC measures are combined, differences between groups are significant. The same holds true for emotional recognition measures. Language abilities that require crystallized intelligence and contribute to SC through pragmatic uses of language—or in the case of this study, uses of humorous language—were compensated for in the aged. On closer look, though, when EF are taken into account, and language compensation is consequently removed from the equation, differences in performance are more pronounced between age groups. This may provide evidence to the argument that EF and SC are two theoretical constructs very interrelated especially in the area of aging where EF decline is one of the first signs of aging. Further research on social cognition in aging should include populations that have a more distinct profile of SC decline in order to distinguish between EF and SC deficits.

Deficiencies in SC in aging are usually considered to be signifiers of later social skills declines, such as increased prejudice and social inappropriateness (von Hippel, 2007). This lack of inhibition is also reflected in brain activation. Older people are reported to show more widespread and attenuated brain activation in almost all areas of the brain (Knyazev, 2007). The present study suggests that delta power band activation could be a good indicator of frontal lobe disinhibition. In the facial recognition experiment, differences between groups in a vast frontocentral area demonstrated possible lack of inhibition. Despite this observation, which is included in a more general framework of a frontal lobe deficiency hypothesis in aging, frontal lobe activation in young adults also seems to be attenuated in tasks that do not require the frontal lobe functions. One explanation for this is that the frontal lobe activation was an indicator of effective compensational mechanisms in healthy older adults since behavioral performance on the facial recognition tasks was similar to that of younger participants. Future research may want to explore this paradigm in individuals with known difficulties in facial recognition, such as patients with certain types of dementia.

The ability of the human brain and the cognitive system to compensate for cognitive mechanisms attenuated by aging also helps emotion recognition through positive emotions perception. The electrophysiological and behavioral findings of this study support the perception of positive facial expressions in the elderly, which seems to vary according to the complexity of the stimuli. As in Metaxas' (2015) study, variation in age group performance appears when stimuli become dynamic, and thus more complex. The present study expanded Metaxa's paradigm by examining the same effect on a sample of educated participants with electrophysiological measures. The results indicated that this observation can be attributed to compensatory mechanisms, which are very effective in educated participants, nevertheless dynamic stimuli are more able to distinguish effects of aging on emotion recognition. In conclusion, dynamic stimuli are not only more complex, but also more ecologically valid, making these results a more accurate description of aging processes.

While the topography of SC was not the purpose of the present study, the results identify two vaguely defined areas of electrode sites connected to SC tasks at different times of processing. In the emotional recognition paradigm, with early processing times, vast frontal area activation supports compensational mechanisms in normal aging, indicating the strong connection between frontal lobes and aging. In the humor perception paradigm, which uses later processing times, posterior regions (connections between temporal-parietal-occipital lobes) of the cortex are more closely connected to age group, confirming that the lack of inhibition observed in the elderly can be measured by delta wave band activation, indicating that those regions are closely connected to the processing of socially relevant information (Samson, Apperly, Chiavarino, & Humphreys, 2004).

Conclusions, limitations, and future directions

This study's main aim was to initiate a systematic research program that could bridge the research gap between behavioral and electrophysiological components of SC in normal aging. In addition to deepening our understanding of the subject, it will pave the way for further theoretical studies on human development and applied programs targeting the wellbeing of the aged. Theoretical hypotheses on brain aging have been partially verified by this study, specifically the frontal lobe hypothesis, compensation hypothesis and lack of inhibition hypothesis. Moreover, this study offers a different, and simpler, explanation of the advantage of processing positive facial expressions for the elderly, relating it to the developmental establishment of positive expressions processing.

Broadly speaking, the results of this study have documented the link between SC and executive functioning and the aging brain's ability to compensate for changes during emotion and humor processing. Further studies should continue to expand on this systematic effort and demonstrate how compensational mechanisms affect SC in aging and the topographies of this process.

Limitations and Future Directions

The present study incorporated EEG measures since this is a very valuable methodology in establishing a more detailed temporal picture of the targeted processes. The EEG through is has limited capacity in identifying topographies of the brain areas involved in the functions described. Future studies should combine EEG paradigms with FMRI or other techniques that are more accurate at describing topographies.

Another important aspect that needs addressing in EEG studies that need to apply a big set of statistical comparisons is the reduction of the alpha level in order to reduce the chances for a Type I error. In Experiment 2, corrections for multiple comparisons were applied. However, the reduction of alpha level may need to be reconsidered for Experiment 3, if future studies employ the specific paradigms.

Future studies in SC could expand the current paradigm and use extensive measures of social inference such as Theory of Mind tasks like social scenarios tests or TASIT tests. Further studies should include such tasks to examine findings on mentalizing abilities and their modulation during aging. The present study used a group of educated older adults so that education would not be a confounding factor in the findings. Future studies could systematically explore the effects of education in social cognitive abilities in order to explore concepts such as cognitive reserve and its role on SC.

In conclusion, this study initiated a systematic research program that could pave the way and bridge the research gap between behavioral and electrophysiological components of SC in normal aging. Future work in this area should continue in order to build an accurate and comprehensive model of adult SC.

Reference List

Adolphs, R. (2001). The neurobiology of social cognition. *Current Opinion in Neurobiology*, *11*(2), 231–239. https://doi.org/10.1016/j.conb.2008.06.003

Albert, M. (1981). Changes in Language with Aging. *Seminars in Neurology*, *1*(1), 43–46. https://doi.org/10.1055/s-2008-1063877

Attardo, S. (1997). The semantic foundations of cognitive theories of humor. *Humor - International Journal of Humor Research*, *10*(4), 395–420. https://doi.org/10.1515/humr.1997.10.4.395

Balconi, M., & Pozzoli, U. (2003). Face-selective processing and the effect of pleasant and unpleasant emotional expressions on ERP correlates. *International Journal of Psychophysiology*, *49*(1), 67–74. https://doi.org/10.1016/S0167-8760(03)00081-3

Balconi, M., & Pozzoli, U. (2009). Arousal effect on emotional face comprehension. Frequency band changes in different time intervals. *Physiology and Behavior*, *97*(3–4), 455–462. https://doi.org/10.1016/j.physbeh.2009.03.023

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test Revised Version: A Study with Normal Adults, and Adults with Asperger Syndrome or High-functioning Autism. *Journal of Child Psychology and Psychiatry*, *42*(2), 241–251. https://doi.org/10.1111/1469-7610.00715

Barrett, S. E., & Rugg, M. D. (1989). Event-related potentials and the semantic matching of faces. *Neuropsychologia*, *27*(7), 913–922. https://doi.org/10.1016/0028-3932(89)90067-5

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research*, *17*(3), 613–620. https://doi.org/10.1016/S0926-6410(03)00174-5

Bekinschtein, T. A., Davis, M. H., Rodd, J. M., & Owen, A. M. (2011). Why Clowns Taste Funny: The Relationship between Humor and Semantic Ambiguity. *Journal of Neuroscience*, *31*(26), 9665–9671. https://doi.org/10.1523/JNEUROSCI.5058-10.2011

Bertrand, M. C., Achim, A., Harvey, P. O., Sutton, H., Malla, A. K., & Lepage, M. (2008). Structural neural correlates of impairments in social cognition in first episode psychosis. *Social Neuroscience*, *3*(1), 79–88. https://doi.org/10.1080/17470910701563491

Blau, V. C., Maurer, U., Tottenham, N., & McCandliss, B. D. (2007). The face-specific N170 component is modulated by emotional facial expression. *Behavioral and Brain Functions : BBF*, *3*, 7. https://doi.org/10.1186/1744-9081-3-7

Bowie, C. R., & Harvey, P. D. (2006). Administration and interpretation of the Trail Making Test. *Nature Protocols*, *1*(5), 2277–2281. https://doi.org/10.1038/nprot.2006.390

Bowlby, J. (1958). the Nature of the Child â€™ S Tie To His Mother. *International Journal of PsychoAnalysis*, *39*, 350–373. https://doi.org/10.1016/j.appdev.2012.08.002

Brandt, J. (1991). The hopkins verbal learning test: Development of a new memory test with six equivalent forms. *Clinical Neuropsychologist*, *5*(2), 125–142. https://doi.org/10.1080/13854049108403297

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R. (2002). Aging Gracefully: Compensatory Brain Activity in High-Performing Older Adults. *NeuroImage*, *17*(3), 1394–1402. https://doi.org/10.1006/nimg.2002.1280

Carstensen, L. L., & Mikels, J. A. (2005). At the Intersection of Emotion and Cognition. *Current Directions in Psychological Science*, *14*(3), 117–121. https://doi.org/10.1111/j.0963-7214.2005.00348.x

Channon, S. (2007). Towards a cognitive and social neuroscience of humor processing. *Social Cognition*, *25*(4), 553–572.

Constantinidou, F., Christodoulou, M., & Prokopiou, J. (2012). The effects of age and education on executive functioning and oral naming performance in greek cypriot adults: The neurocognitive study for the aging. *Folia Phoniatrica et Logopaedica*, *64*(4), 187–198. https://doi.org/10.1159/000340015

Constantinidou, F., Wertheimer, J. C., Tsanadis, J., Evans, C., & Paul, D. R. (2012). Assessment of executive functioning in brain injury: Collaboration between speech-language pathology and neuropsychology for an integrative neuropsychological perspective. *Brain Injury*, *26*(13–14), 1549–1563. https://doi.org/10.3109/02699052.2012.698786

Coulson, S. (2004). Electrophysiology and pragmatic language comprehension. In J. Meibauer (Ed.), *Experimental Pragmatics* (pp. 187–206). https://doi.org/10.1057/9780230524125_9

Covington, M. A., He, C., Brown, C., Naçi, L., McClain, J. T., Fjordbak, B. S., … Brown, J. (2005). Schizophrenia and the structure of language: The linguist's view. *Schizophrenia Research*, *77*(1), 85–98. https://doi.org/10.1016/j.schres.2005.01.016

Davidson, R. J., Scherer, K. R., & Goldsmith, H. H. (2009). *Handbook of affective sciences*. New York: Oxford University Press.

Du, X., Qin, Y., Tu, S., Yin, H., Wang, T., Yu, C., & Qiu, J. (2013). Differentiation of stages in joke comprehension: Evidence from an ERP study. *International Journal of Psychology*, *48*(2), 149–157. https://doi.org/10.1080/00207594.2012.665162

Dunn, L., & Dunn, D. (1965). *Peaboby Picture Vocabulary Test* (American G).

Dustman, R. E., LaMarche, J. a, Cohn, N. B., Shearer, D. E., & Talone, J. M. (1985). Power spectral analysis and cortical coupling of EEG for young and old normal adults. *Neurobiology of Aging*, *6*(3), 193–8. https://doi.org/10.1016/0197-4580(85)90049-1

Duval, C., Piolino, P., Bejanin, A., Eustache, F., & Desgranges, B. (2011). Age effects on different components of theory of mind. *Consciousness and Cognition*, *20*(3), 627–642. https://doi.org/10.1016/j.concog.2010.10.025

Ecker, C., Suckling, J., Decont, S., Lombardo, M. V., Bullmore, E. T., & Baron-Cohen, S. (2012). Brain Anatomy and Its Relationship to Behavior in Adults With Autism Spectrum Disorder, *69*(2), 195–209.

Eimer, M., & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Cognitive Neuroscience and Neuropsychology*, *13*(4), 1–5.

Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia*, *45*(1), 15–31. https://doi.org/10.1016/j.neuropsychologia.2006.04.022

Ekman, P., Friesen, W. V., & Hager, J. C. (2002). Facial Action Coding System: The manual on CDROM. Salt Lake City: Research Nexus division of Network Information Research Corporation.

Federmeier, K. D. (2014). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *NIH Public Access*, 621–647. https://doi.org/10.1146/annurev.psych.093008.131123.Thirty

Feng, Y. J., Chan, Y. C., & Chen, H. C. (2014). Specialization of neural mechanisms underlying the three-stage model in humor processing: An ERP study. *Journal of Neurolinguistics*, *32*, 59–70. https://doi.org/10.1016/j.jneuroling.2014.08.007

Feuerriegel, D., Churches, O., Hofmann, J., & Keage, H. A. D. (2015). The N170 and face perception in psychiatric and neurological disorders: A systematic review. *Clinical Neurophysiology*, *126*(6), 1141–1158. https://doi.org/10.1016/j.clinph.2014.09.015

Fiske, S., & Taylor, S. (2013). *Social Cognition: From Brain to Culture* (2nd ed.). London: Sage.

Forabosco, G. (2008). Is the concept of incongruity still a useful construct for the advancement of humor research? *Lodz Papers in Pragmatics*, *4*(1), 45–62. https://doi.org/10.2478/v10016-008-0003-5

Friedman, D. (2011). The Components of Aging. In *Eventrelated potentials - a methods handbook.*

Frith, C. D., & Frith, U. (2007). Social Cognition in Humans. *Current Biology*, *17*(16), 724–732. https://doi.org/10.1016/j.cub.2007.05.068

Frith, C. D., & Frith, U. (2012). Mechanisms of Social Cognition. *Annual Review of Psychology*, *63*(1), 287–313. https://doi.org/10.1146/annurev-psych-120710-100449

Giogkaraki, E., Michaelides, M. P., & Constantinidou, F. (2013). The role of cognitive reserve in cognitive aging: Results from the neurocognitive study on aging. *Journal of Clinical and Experimental Neuropsychology*, *35*(10), 1024–1035. https://doi.org/10.1080/13803395.2013.847906

Golan, O., Sinai-Gavrilov, Y., & Baron-Cohen, S. (2015). The Cambridge Mindreading Face-Voice Battery for Children (CAM-C): complex emotion recognition in children with and without autism spectrum conditions. *Molecular Autism*, *6*(1), 22. https://doi.org/10.1186/s13229-015-0018-z

Gunning-Dixon, F. M., Gur, R. C., Perkins, A. C., Schroeder, L., Turner, T., Turetsky, B. I., … Gur, R. E. (2003). Age-related differences in brain activation during emotional face processing. *Neurobiology of Aging*, *24*(2), 285–295. https://doi.org/10.1016/S0197-4580(02)00099-4

Gunter, T. C., Jackson, J. L., & Mulder, G. (1995). Language, memory, and aging: An electrophysiological exploration of the N400 during reading of memory- demanding sentences. *Psychophysiology*, *32*(3), 215–229. https://doi.org/10.1111/j.1469-

8986.1995.tb02951.x

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2011). ERPs and the Study of Emotion. In J. S. Luck & S. E. Kappenman (Eds.), *The Oxford Handbook of Event Related Potential Components*.

Harmony, T. (2013). The functional significance of delta oscillations in cognitive processing. *Frontiers in Integrative Neuroscience*, *7*(December), 1–10. https://doi.org/10.3389/fnint.2013.00083

Harmony, T., Fernandez, T., Silva, J., Bernal, J., Lourdes, D., Reyes, A., … Rodriguez, M. (1996). EEG delta activity: an indicator to attention to internal processing during performance of mental tasks. *International Journal of Psychophysiology*, *24*, 161–171.

Hasher, L., Tonex, S. T., Lustig, C., & Zacks, R. T. (2001). Inhibitory control, environmental support, and self-initiated processing in aging. *Perspectives on Human Memory and Cognitive Aging: Essays in Honour of Fergus Craik* .

Helfrich, R. F., Huang, M., Wilson, G., & Knight, R. T. (2017). Prefrontal cortex modulates posterior alpha oscillations during top-down guided visual perception. *Proceedings of the National Academy of Sciences*, (model 2), 201705965. https://doi.org/10.1073/pnas.1705965114

Holmes, A., Winston, J. S., & Eimer, M. (2005). The role of spatial frequency information for ERP components sensitive to faces and emotional facial expression. *Cognitive Brain Research*, *25*(2), 508–520. https://doi.org/10.1016/j.cogbrainres.2005.08.003

Ibáñez, A., Riveros, R., Hurtado, E., Gleichgerrcht, E., Urquina, H., Herrera, E., … Manes, F. (2012). The face and its emotion: Right N170 deficits in structural processing and early emotional discrimination in schizophrenic patients and relatives. *Psychiatry Research*, *195*(1–2), 18–26. https://doi.org/10.1016/j.psychres.2011.07.027

Knyazev, G. G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neuroscience and Biobehavioral Reviews*, *31*(3), 377–395. https://doi.org/10.1016/j.neubiorev.2006.10.004

Knyazev, G. G. (2012). EEG delta oscillations as a correlate of basic homeostatic and motivational processes. *Neuroscience and Biobehavioral Reviews*, *36*(1), 677–695. https://doi.org/10.1016/j.neubiorev.2011.10.002

Konstantinou, N., Pettemeridou, E., Seimenis, I., Eracleous, E., Papacostas, S. S., Papanicolaou, A. C., & Constantinidou, F. (2016). Assessing the relationship between neurocognitive performance and brain volume in chronic moderate-severe traumatic brain injury. *Frontiers in Neurology*, *7*(MAR), 1–13. https://doi.org/10.3389/fneur.2016.00029

Kurtz, M. M. (2011). Neurocognition as a predictor of response to evidence-based psychosocial interventions in schizophrenia: What is the state of the evidence? *Clinical Psychology Review*, *31*(4), 663–672. https://doi.org/10.1016/j.cpr.2011.02.008

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological Assessment*. Oxford: Oxford University Press.

Lombardo, M. V., Chakrabarti, B., Bullmore, E. T., & Baron-Cohen, S. (2011).

Specialization of right temporo-parietal junction for mentalizing and its relation to social impairments in autism. *NeuroImage*, *56*(3), 1832–1838. https://doi.org/10.1016/j.neuroimage.2011.02.067

Lombardo, M. V, Chakrabarti, B., Bullmore, E. T., Wheelwright, S. J., Sadek, S. a, Suckling, J., & Baron-Cohen, S. (2010). Shared neural circuits for mentalizing about the self and others. *Journal of Cognitive Neuroscience*, *22*(7), 1623–35. https://doi.org/10.1162/jocn.2009.21287

Lough, S., Gregory, C., & Hodges, J. R. (2001). Dissociation of social cognition and executive function in frontal variant frontotemporal dementia. *Neurocase : Case Studies in Neuropsychology, Neuropsychiatry, and Behavioural Neurology*, *7*(2), 123–130. https://doi.org/10.1093/neucas/7.2.123

Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in Cognitive Sciences*, *9*(10), 496–502. https://doi.org/10.1016/j.tics.2005.08.005

Metaxas, G. (2015). *Social Cognition during normal aging . Investigation of Social Cognition in relation to other cognitive aspects and quality of life*. University of Cyprus.

Metaxas, G., Shoshilou, P., & Costantinidou, F. (2016). Measuring Social Cognition in Greek: Psychometric Properties from an Adaptation study in the Adult Greek-Cypriot Population. In *INS mid year meeting proceedings july 2016*. London.

Moran, J. M. (2013). Lifespan development: The effects of typical aging on theory of mind. *Behavioural Brain Research*, *237*(1), 32–40. https://doi.org/10.1016/j.bbr.2012.09.020

Nasreddine, Z. (2010). Montreal Cognitive Assessment, *53*(4), 1–4. Retrieved from http://www.mocatest.org/wp-content/uploads/2015/tests-instructions/MoCA-Test-English_7_1.pdf

Park, D. C., & Reuter-Lorenz, P. (2009). The Adaptive Brain: Aging and Neurocognitive Scaffolding. *Annual Review of Psychology*, *60*(1), 173–196. https://doi.org/10.1146/annurev.psych.59.103006.093656

Pavanin, L. A. (2008). AGING AND ATTENTIONAL BIASES FOR EMOTIONAL FACES. *Water*, *466*(October 2007), 458–466. https://doi.org/10.1002/em

Penn, D. L., Sanna, L. J., & Roberts, D. L. (2008). Social cognition in schizophrenia: An overview. *Schizophrenia Bulletin*, *34*(3), 408–411. https://doi.org/10.1093/schbul/sbn014

Ramaraju, S., Izzidien, A., & Roula, M. A. (2015). The detection and classification of the mental state elicited by humor from EEG patterns. *Conference Proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference*, *2015*, 1472–5. https://doi.org/10.1109/EMBC.2015.7318648

Rellecke, J., Sommer, W., & Schacht, A. (2013). Emotion effects on the N170: A question of reference? *Brain Topography*, *26*(1), 62–71. https://doi.org/10.1007/s10548-012-0261-y

Reuter-Lorenz, P. A. (2002). New visions of the aging mind and brain. *Trends in Cognitive Sciences*, *6*(9), 394–400. https://doi.org/10.1016/S1364-6613(02)01957-5

Reuter-Lorenz, P. A., & Cappell, K. A. (2008). Neurocognitive aging and the compensation hypothesis. *Current Directions in Psychological Science*, *17*(3), 177–182. https://doi.org/10.1111/j.1467-8721.2008.00570.x

Rossion, B., & Jacques, C. (2011). The N170: Understanding the Time Course of Face Perception in the Human Brain. In J. S. Luck & S. E. Kappenman (Eds.), *The Oxford Handbook of Event Related Potential Components*. Oxford University Press.

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1996). Benton controlled Oral Word Association Test: Reliability and updated norms. *Archives of Clinical Neuropsychology*, *11*(4), 329–338. https://doi.org/10.1016/0887-6177(95)00033-X

Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology*, *54*(1–3), 35–54. https://doi.org/10.1016/S0301-0511(00)00052-1

Saltzman, J., Strauss, E., Hunter, M., & Archibald, S. (2000). Theory of mind and executive functions in normal human aging and Parkinson's disease. *Journal of the International Neuropsychological Society*, *6*(7), 781–788.

Samson, D., Apperly, I. A., Chiavarino, C., & Humphreys, G. W. (2004). Left temporoparietal junction is necessary for representing someone else's belief. *Nature Neuroscience*, *7*(5), 499–500. https://doi.org/10.1038/nn1223

Sato, W., Kochiyama, T., Yoshikawa, S., & Matsumura, M. (2001). Emotional expression boosts early visual processing of the face: ERP recording and its decomposition by independent component analysis. *Neuroreport*, *12*(4), 709–714. https://doi.org/10.1097/00001756-200103260-00019

Saxe, R. (2006). Uniquely human social cognition. *Current Opinion in Neurobiology*, *16*(2), 235–239. https://doi.org/10.1016/j.conb.2006.03.001

Shammi, P., & Stuss, D. T. (1999). Humour appreciation: a role of the right frontal lobe. *Brain*, *122*(4), 657–666. https://doi.org/10.1093/brain/122.4.657

Shin, M.-S., Park, S.-Y., Park, S.-R., Seol, S.-H., & Kwon, J. S. (2006). Clinical and empirical applications of the Rey–Osterrieth Complex Figure Test. *Nature Protocols*, *1*(2), 892–899. https://doi.org/10.1038/nprot.2006.115

Smith, A. (1968). The symbol-digit modalities test: a neuropsychologic test of learning and other cerebral disorders. *Learning Disorders*, 83–91.

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, *47*(10), 2015–2028. https://doi.org/10.1016/j.neuropsychologia.2009.03.004

Strathearn, L., Li, J., Fonagy, P., & Read, P. (2009). NIH Public Access. *Psychiatry: Interpersonal and Biological Processes*, *122*(1), 40–51. https://doi.org/10.1542/peds.2007-1566.What

Stuss, D. T. (2011). Functions of the Frontal Lobes: Relation to Executive Functions. *Journal of the International Neuropsychological Society*, *17*(5), 759–765. https://doi.org/10.1017/S1355617711000695

Sulz, J. (1972). A Two-Stage Model for the Appreciation of Jokes and Cartoons: An Information-Processing Analysis. In J. Goldstein (Ed.), *The Psychology of Humor* (pp.

61–80). Eslevier.

Towler, J., & Eimer, M. (2015). Early stages of perceptual face processing are confined to the contralateral hemisphere: Evidence from the N170 component. *Cortex*, *64*, 89–101. https://doi.org/10.1016/j.cortex.2014.09.013

Tu, S., Cao, X., Yun, X., Wang, K., Zhao, G., & Qiu, J. (2014). A New Association Evaluation Stage in Cartoon Apprehension: Evidence from an ERP study. *Journal of Behavioral and Brain Sciences*, *4*, 75–83.

Uekermann, J., Channon, S., & Daum, I. (2006). Humor processing, mentalizing, and executive function in normal aging. *Journal of the International Neuropsychological Society : JINS*, *12*(2), 184–91. https://doi.org/10.1017/S1355617706060280

Vaid, J., Hull, R., Heredia, R., Gerkens, D., & Martinez, F. (2003). Getting a joke: The time course of meaning activation in verbal humor. *Journal of Pragmatics*, *35*(9), 1431–1449. https://doi.org/10.1016/S0378-2166(02)00184-4

von Hippel, W. (2007). Agining, executive functioning, and social control. *Current Directions in Psychological Science*, *16*(5), 240–243. https://doi.org/10.1111/j.1467-8721.2007.00512.x

Vygotsky, B. L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press.

Wallace, J. . (1984). Wechsler Memory Scale. *International Journal of Clinical Neuropsychology*, *6*(3), 216–226.

Wang, R. W. Y., Kuo, H.-C., & Chuang, S.-W. (2017). Humor drawings evoked temporal and spectral EEG processes. *Social Cognitive and Affective Neuroscience*, (September), 1–18. https://doi.org/10.1093/scan/nsx054

West, R. L. (2000). In defense of the frontal lobe hypothesis of cognitive aging. *Journal of the International Neuropsychological Society : JINS*, *6*(6), 727–729; discussion 730. https://doi.org/10.1017/S1355617700666109

Whalley, L. J., Deary, I. J., Appleton, C. L., & Starr, J. M. (2004). Cognitive reserve and the neurobiology of cognitive aging. *Ageing Research Reviews*, *3*(4), 369–382. https://doi.org/10.1016/j.arr.2004.05.001

Wild, B., Rodden, F. A., Grodd, W., & Ruch, W. (2003). Neural correlates of laughter and humour. *Brain*, *126*(10), 2121–2138. https://doi.org/10.1093/brain/awg226

Williams, J. H. G., Whiten, A., Suddendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience and Biobehavioral Reviews*, *25*(4), 287–295. https://doi.org/10.1016/S0149-7634(01)00014-8

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1982). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research*, *17*(1), 37–49. https://doi.org/10.1016/0022-3956(82)90033-4

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica*, *115*(2–3), 167–183. https://doi.org/10.1016/j.actpsy.2003.12.005