Prepulse inhibition

as an index of attentional processing:

A comparison between

young and elderly

Hovedoppgaven til Cand. Psychol. graden
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Forord

Tanken om hovedoppgave vedrørende dette temaet, ble til da jeg leste en artikkel som undersøkte PPI og demens. Til tross for interessen, ble vanskelig å gjøre et studie på demens pasienter i Tromsø, og oppgaven omhandler derfor PPI hos unge og normale eldre.

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Abstract

Prepulse inhibition (PPI) is assumed to index attentional processes by inhibition of the startle reflex. By directing attention towards a weak stimulus, i.e., the prepulse, PPI is increased. We investigated controlled and automatic processes related to attention in young and elderly subjects. Both groups (n=41) attended to a task where they were to judge if length of a comparison tone was shorter or longer than prepulse. Degree of PPI was assessed by different stimulus onset asynchronies (SOA) assumed to index automatic and controlled processing. We predicted firstly that the young would show established PPI values. Secondly, that normal elderly would show a increase in PPI compared to young when attending to task compared to no-task. As predicted, we found normal PPI function in the young. In the elderly, the expected hyperbolic and quadric PPI function failed to display. Thus, a straight PPI line suggests a continuously elaborating of the first prepulse and pulse in task and No-task, meaning that task made no difference in attentional processing in the elderly. The hypothesis of a global decline in inhibitory function in elderly is suitable as an explanation for reduction in PPI, and we assume that results is due to inhibitory problems in attention, as a consequence of physiological aging in cortex.

Introduction

Common for all humans is aging. It is well established that physiological, as well as cognitive capacity, is reduced when the years go by. As cognitive resources degrade, is it natural to think that selective attention will be reduced (McDowd & Filion, 1992).

Attentional Process

It is common to divide attention in two processes. Automatic processes are silent in the sense that they operate outside conscious awareness, and refer to the processes of detection, analysis, and identification of stimuli. They occur at Stimulus Onset Asynchrony (SOA) of less than 120 ms (Dawson, Schell, Swerdlow & Fillion, 1997). The individual merely detects a stimuli and the process of detecting simple features like intensity, pitch and shape (Öhman, 1997) takes place. Thus, what eventually is experienced as an conscious experience by the subject, are not raw material, but elaborated sensory information that already been processed (Cook III & Turpin, 1997). This process happens unconsciously, automatic, quickly and effortless, in a way that the individual have no recollection of the process that just took place (Elden, 2002).

In controlled processing, only a fraction of the incoming stimuli are chosen for further processing (Elden, 2002). It occurs relatively slowly and is dependent on conscious awareness, and occur at SOA longer than 120 ms (Dawson et al., 1997). Since it is dependent on limited attentional resources, under intentional control, and associated with conscious experience (Dawson et al., 1997), this is the processing the subject is able to recollect

Attention In Aging

In psychology, attention is viewed as capacity to, or energy to support cognitive processing (Lezak, 1995). A central division is between controlled and automatic processes. A deficit in selective attention may be central to explain changes in cognitive performance during aging, and there is evidence of an age deficit in selective attention (Hasher & Zacks, 1979; Kausler, 1994). Selective attention is the phenomenon that one attends to the stimuli of most interest, and filter out irrelevant stimuli. According to two-process theories of selective attention (Posner & Snyder,1975), facilitation of relevant stimuli and inhibition of irrelevant stimuli constitute different aspects of selective attention.

Common for theories postulating deficits in selective attention, is the result of a deficit in inhibitory functions (Ellwanger, Geyer & Braff, 2003), and with aging selective attention declines due to a failure in inhibitory versus facilitory processes. Salthouse (1985, 1988) claims that age-related differences in attentional functioning are the result of a reduction in the energy that "fuels" cognitive processing, and this fuel can be increased by arousal (Kahneman, 1973).

By using Skin Conductanse Orienting Response (SCOR), McDowd & Filion (1992) postulated that elderly would show increment in inhibitory functions, and as a consequence allocate their attentional resources less efficiently than young adults. Their investigation was performed in the context of the "Dual- Process model of selective attention", a model that emphasize both selection of relevant stimuli and inhibition of irrelevant information. This model has been developed theoretically and empirically after Triesman's model of 1969 (as cited in McDowd & Fillion, 1992). The subject was instructed to attend toward a story, or some noises (75 dB, 1000 Hz) presented during low loudness of the story. The noise was presented simultaneously with the story, and the subject had to ignore noise or story. Results show that the young adults were more accurate than the elderly, and the elderly were less able to inhibit responding to irrelevant stimuli than the young. The authors stated that inhibitory processes were compromised in the elderly, and this produced a deficit in selective attention. These results are in accordance with data suggesting that older adults have reduced inhibitory control relative to young adults (McDowd & Fillion, 1992).

Working Memory.

Hasher & Zacks (1979, 1984, 1988) found that automatic encoding processes were presumably unaffected by a persons limited resources. They proposed a "capacity theory", stating that working memory (WM) is reduced with aging because less efficient inhibitory process fail to prevent irrelevant information from entering, or being processed, in WM. That storage functions is reduced with aging, comes from evidence suggesting that task that make demands on the storage component, have a particularly disruptive effect on the elderly compared with younger adults (Hasher & Zacks, 1988; Light & Capp, 1986). The notion of limited capacity and different demands on that capacity, are most often embedded in the concept of working memory (Hasher & Zacks, 1988). Working memory is conceived as a limited capacity mechanism which share its resources between a storage function and a set of processing functions (i.e. attentional analysis). Demanding tasks may place a large burden on storage function in WM, thus having access to prior knowledge about the demanding task, will relive strength on the total amount of capacity available. This process can be expected to malfunction, preventing new inferences from being drawn, and preventing the representation of a general construction of the stimuli (Hasher & Zacks, 1988). The capacity model assumes that there is a competition between processing and storage, and due to the decreasing supply of capacity in the elderly, the processing component of WM has higher priority than the storage compartment.

The model involves two basic mechanism of selective attention, namely activation and inhibition. Inhibition is suppressing of irrelevant information so that such information is less likely to have access to WM, and irrelevant information and previously relevant information that does enter WM, is quickly removed. Attentional inhibition may also have the function of preventing the return of attention to a previously rejected item. The presence of this irrelevant information results in poor encoding, retrieval, and comprehension of incoming information (Zacks, Radvansky & Hasher, 1996).

Critics argue that the major limitation of the theory, is the establishing of good measures of attentional capacity.

To measure attentional capacity, startle eyeblink modification (SEM) is a common measure and have proven reliable (Fillion, Dawson & Schell, 1998).

Startle Eyeblink Modification

Startle eyeblink modification involves a relatively intense stimulus (e.g. a sudden loud noise), which elicits a startle eyeblink reflex. The nature of SEM have been divided in two main classes, the first is modification and latency of the reflex by lead stimuli presented up to approximately 500 ms (called short lead interval effects), and second; modification with lead stimuli presented longer than 500-800 ms prior to the startle reflex (called long lead interval effects)(Fillion et al. 1998).). Thus, to achieve inhibition, short lead interval effects of 15 to about 400 ms (Graham, 1975; Elden & Flaten, 2002, 2003) is most common.

The time period between the lead stimulus (prepulse) and the startle- eliciting stimulus (pulse) determines if the lead stimulus facilitates or inhibits the strength of the reflex, and is known as Stimulus Onset Asynchronies (SOA). If the lead stimulus (prepulse) inhibits the startle reflex (pulse), the paradigm is known as Prepulse Inhibition (PPI). The strength of the reflex in the presence of the lead stimulus gives an image of the attention processes taking place in the subject. A weak prepulse seems to demand or dominate automatic processing capacity and inhibit startle reflex to subsequent stimuli. The automatic process is considered to be unconscious, fast and parallel in the sense that it can be performed together with other processes (Öhman, 1997), thus the amount of PPI can be used as an involuntary, nonverbal, index of automatic processing.

The most reliable component of startle is the eyeblink reflex (Landis & Hunt, 1939), a robust effect considered quite reliable and occurring in 90-100 % of normal adult participants (Fillion et al., 1998).

SEM has proven suitable for the investigation of a global loss of inhibitory function, mainly because startle plasticity is assumed to give direct indices of inhibition (Fillion et al, 1998).

Startle Eyeblink Modification In Aging.

SEM in the elderly has not previously received much attention. However, a few studies have been performed. Harbin and Berg (1983,) found inhibition of airpuff elicited reflexes at an SOA of 420 ms in both young (mean = 20 years) and elderly (mean = 68 years) subjects. In a second study (Harbin & Berg, 1986), the participants did an attention demanding visual search task. By comparing young (mean = 19) and elderly (mean = 69), they reported no significant effect of age on PPI. Nearly significant results in age by condition interaction, indicated that young participant demonstrate more PPI during a condition engaging a task versus no task. The old subjects demonstrated equal PPI in task and No-task condition (Harbin & Berg, 1986; Ellwanger et al., 2003). However, Ford et al., (1997) found that young persons (18-25 years) demonstrated greater frequency of startle blink to loud noises than elderly (58-76years).

Flaten and Powell (1998) investigated whether young and older subjects would show similar or different rates of reflex facilitation as a result to previous exposure to classical conditioning. In two age groups, one group (paired group) received a classical conditioning paradigm consisting of 70 trials, where the unconditioned stimuli (US) was an airpuff to the eye. Second group (unpaired group) received equal airpuff and same number of trials, but the stimuli was presented in a way that no conditioning took place. Result showed increased conditioning in the paired group consisting of young participants, with no conditioning in the elderly group. Further, there was increased reflex amplitudes in the young group compared to the old. The elderly displayed startle facilitation when conditioned, compared to reflexes elicited alone without conditioning present. There was no difference in noise elicited eyeblink amplitudes between young and elderly subjects.

To see whether reduced Conditioned responses (CRs) in the elderly could be due to decreased Unconditional Response (UR), Flaten & Friborg (2005) investigated if reduced autonomic activation might explain the impaired acquisition of eyeblink Conditioned Respons (CR). This was based on literature discussing if smaller reflex amplitude might be due to decreased orbicularis oculi activation that control blink, or reduced sensory abilities. Participants were divided in two groups, young (mean 23) and elderly (mean 73). Participants was conditioned to airpuff and tones, and startle eliciting noises was used as a measure of reflex strength. The results showed a significant higher startle reflex magnitude in the young subject compared to the elderly. The young subject also showed increased startle reflex in the presence of CS compared to the elderly. In sum, significantly more frequent and larger eyeblink in young than in the elderly subject, data supporting Flaten & Powell (1998). However, startle facilitation was not related to conditioning in the old, contrary to Flaten and Powell.

In a study concerning PPI in patients with Alzheimer, Hejl, Glenthøj, Mackeprang, Hemmingsen & Waldemar. (2003) used normal elderly (> 60 years) as control group. Their results in a passive paradigm and with continuous background noise, was significant PPI in SOA 30, 60, and 120 ms, compared to the pulse alone condition.

Ellwanger et al. (2003) were the first to investigate the relationship between age and PPI. They hypothesized that aging would give a global decline in inhibitory functions, such as ability to ignore relatively irrelevant sensory, cognitive, or motor information. The participants consisted of four age groups spread among college students, young, middle age and old. The groups were not equally spread. All the participants were tested on part A and B of the Trail Making test, to investigate perceptual-motor speed and cognitive flexibility. In the experiment the participant's were exposed to a "passive paradigm" (where they are not attending attention to any aspect of the experiment) with continuing background noise of 75dB. The SOA was 30 and 120 ms. Results showed that startle reflex had a slowing (latency decrease) and decline (magnitude decrement) with aging. Further, the results showed that the middle age group displayed the most PPI, and the college group the least. The most extreme age groups did not display any significant PPI effect, a finding that does not support the original expectation of general decrease in inhibitory function with age, thus a finding consistent with Harber & Berg (1983, 1986). Though, what remains unclear is how the elderly will process PPI if they attend to a task.

Animal Studies.

In rodents, startle is typically measured by using the whole body-flinch that occur in response to the startle stimuli. Of the most strongly supported research findings say that startle magnitude decreases with increasing age in both mice and rodents (Ison, Bowen, Pak & Gutierrez, 1997; Ellwanger et al., 2003). Ison et al. (1997) studied mice of three ages (young, middle age, and old). Results revealed that startle response decreased with increasing age, and that percent PPI was not affected by age. By using rats of four ages (young, adult, middle age, and old), Varty, Haugher & Geyer, (1998) found that when acoustic or tactile stimuli was used to elicit startle, the old group consistently had the smallest magnitude. The condition of auditory stimuli, showed no effect of age on either PPI or startle, when ratio measures was corrected for age-related changes.

Neurobiology Of Startle Eyeblink Modification.

The neurobiology of startle and PPI has been described. The SEM indicate central nervous system activity, and this activity can be measured as electrical activity to the muscles. The muscle activity is driven by a set of neurons in the brain stem (Elden, 2002), described in rats by Lee et al. (1996) (as cited in in Elden, 2002). The first synapse is the cochlear root in the auditory nerve, a small nucleus made of very large cells. The cochlear root axon terminates directly in the nucleus Reticularis Pontis Caudalis (nRPC), situated in the medial tegmental pons. This nucleus is known as the startle center because electrical stimulation in this area elicits a startle respons, and lesions abolish it. From nRPC motoneurons project in the spinal cord, to the facial nucleus (nerve VII), that controls the pinna and the blink reflexs (Elden, 2002). A Positron Emission Tomography (PET) -study by Pissiota, Frans, Fredrikson, Langstrøm & Flaten. (2002) confirmed that this center was activated by startling noise in humans.

What Causes PPI

Inhibitory functions in SEM operate in automatic and controlled processing. The different SOA for these processes, are related to two main theories.

The Protection Of Processing Hypothesis

According to Graham (1975, 1992) there are two parallel processes that occur when a stimulus is perceived. The first is encoding and perceptual analysis of the stimulus, and the second is a protective process that attenuates all subsequent stimuli until the encoding of the stimuli is completed. Together the processes are called “The protection of processing hypothesis”. The rationale in this theory states that a startle stimulus would be perceived less intense if the prepulse reduce the available capacity to the attention system.
Simple physical features such as intensity and pitch are detected and analyzed automatically. Cohen, Hoffman & Stitt (1981) used 80 dB tone as prepulse, and a tap on the forehead

(glabellar tap) as pulse. They found that the presence of the prepulse decreased both the size of the eyeblink elicited by the tap as well as the estimated intensity of the tap itself. Perlstein, Fiorito, Simons & Graham (1993) obtained similar results, using a 75 dB tone as prepulse, and 110 dB tone as pulse.

The theory further state that perception analysis of the prepulse will influence the response to the pulse, i.e., the startle-eliciting stimulus. The analysis of the prepulse reduces processing of the startle stimulus, and inhibits the reflex. If startle inhibition serves to protect the perceptual processing of the pulse, then perception of prepulse should be more accurate when it is effective in producing startle inhibition (Fillion et al., 1998).

Norris and Blumenthal (1995) instructed participants to indicate after each trial, whether a high-pitched prepulse, a low-pitched prepulse, or no prepulse had been present. Because the tone pitches was difficult to discriminate, these investigators were able to use the number of hits and misses for the target lead stimuli as a measure of the accuracy of lead stimuli perception. Results revealed that greater startle inhibition was produced on trials in which the lead stimulus was correctly identified.

Elden and Flaten (2003) asked participants to judge whether a tone prepulse was shorter or longer than a comparison tone presented before prepulse. To make the task more difficult, a distracting airpuff was presented simultaneously with the tone prepulse. In experiment two, an airpuff was used as prepulse, and a tone was used as distracter. In the no task condition, the participants were instructed to not pay attention to the prepulse. The hypothesis was that more difficult task should increase PPI, because it would demand more attentional resources and hereby inhibit pulse compared to less demanding tasks. By presenting a distracter simultaneously with prepulse, the task difficulty should increase. Results showed that by changing the modality on prepulse, directing attention to both acoustic and tactile prepulse increased pulse according to established theory. Further, inhibition increased at SOA of 30, 60, and 420 ms.In sum, the presented experiments support the rationale presented in Protection of processing hypothesis. Results show that short lead interval effects (below 500 ms) inhibit the pulse according to automatic processes, and support the theory first and second processes. Long lead interval stimuli (above 500 ms) facilitate pulse according to controlled processing of stimuli. This supports the theory stating that analysis of the stimuli are completed and attentional resources are ready to interpret new sensory stimuli.

The Sensorimotor Gating Hypothesis

Braff and Geyer (1990) view startle inhibition in a similar way as Protection of processing hypothesis. They stated that startle inhibition may serve as an operational measure of sensorimotor gating , "reflecting the ability to effectively buffer or screen out the potentially chaotic flow of information and sensory stimuli" (as cited in Cadenhead, Geyer & Braff, 1993). Startle inhibition is a basic function that inhibits sensory input, allowing the brain to process and elaborate the early stages of information processing. It is preattentive and automatic at very short interval (60ms), but may be controlled at longer lead interval (Elden, 2002). What differentiates this hypothesis from Protection-of-processing theory, is the suggestion that startle inhibition reflects a general ability to inhibit external stimuli (e.g. auditory, visual, tactile) as well as internal stimuli (such as thoughts and impulses)(Geyer, Swerdlow, Mansbach & Braff, 1990). In support of this theory is literature reporting deficits in startle among schizophrenia patients, obsessive-compulsive disorder, college students scoring high on psychosis-proneness scale, Huntington's disease, and children with Attention-deficit-disorder (as cited in Fillion et al., 1998).

Relationship to attentional processing

What remains unclear in both protection of processing hypothesish and sensorimotor gating hypothesis, are whether PPI occurs automatically, or are dependent of controlled attentional processing. Observation of startle inhibition in nonhuman animals, decorticated rats, in infants, sleeping adult humans, and the fact that pre-habituation does not affect startle inhibition in either humans or animals (Fillion et al., 1998), suggest that this inhibition is an automatic process. At the same time this does not exclude that inhibition could be modulated by controlled attentional processes. Delpezzo and Hoffman (1980) found that startle inhibition was greater in trials where the participants knew the location of a light in front of them. The participant's was instructed to gaze at a grid of light located directly in front of them. In the first experiment, participants were warned on half on the trials where the light would appear, and were given no information on the other half. Results of interest are that PPI was inhibited on trials where the participants were instructed to see where the light would appear, that a focus on the prepulse increase the amount of inhibition on the pulse. In a second, experiment they altered the procedure so that participants were instructed to focus on the light in half of the presentations, and the other half to focus 40 degree left to the grid position. In this experiment the light in the central position of the grid was on continuously. Result revealed that inhibition of pulse was greater when participant was instructed to focus on the light in the central position, than when they should focus to the left of the light. Results seems to support that controlled attentional processing inhibit pulse.

Elden and Flaten (2002) had hypothesis that prepulse would increase PPI, and that PPI should increase on trials with correct judgement of prepulse duration. By instructing the subjects to listen to a comparison tone previous the prepulse, the task was to judge whether prepulse was shorter or longer than the comparison tone. The results from this first experiment, as an between-subject design, showed that judgment of the duration of the prepulse increased PPI. It was hypothesized that the amount of attention directed to the prepulse, the higher was the probability that they would judge correct. Result revealed that paying attention to the prepulse increased PPI, but performing well on the task did not accentuate PPI further. In a second experiment the participants, as a part of a within-subject design, did the same task as in the first experiment. Results replicated finding from experiment one, that the reflex is inhibited by attention to the prepulse. Overall findings are that PPI increase over different SOA if the prepulse are attended to.

To investigate whether different SOA in long lead interval was affected, Schell, Dawson, Hazlett & Fillion (1995) investigated attentional modulation. The participants were instructed to perform a triple task: 1) listen to a series of high and low pitch tones: 2) to silently count the longer than usual high pitched tones; and 3) to ignore the low pitched tones. The standard length of the tones was 5 seconds, and the longer than usual tones was 7 seconds in duration. Results revealed that control participants had greater inhibition of startle blink at 120 ms and greater facilitation at 2000 ms during the to-be-attended task. Filion et al. (1993, 1994) did an experiment following the same experimental procedure, where subject was presented with 5 and 7 seconds intermixed tones of different pitch. The task was to keep count of 7 seconds tone of one pitch, and to ignore the others. Similar to Hazlett & Fillion (1995), PPI at SOA 2000 ms was facilitated with greater facilitation when attending to task. Jennings et al. (1996) did a follow up study, investigating SOA 2000, 4500 and 6000 ms. They found that greatest facilitation was observed in 6000 and 4500 ms compared to 2000 ms, and that attending to task gave greater facilitation compared to not attending to task. Jennings et al. (1996) claim that the degree of facilitation appeared to reflect task difficulty, though the results indicate that the amount of startle facilitation at long lead interval is a function of attentional processing.

In summary, the present experiments support the notion that controlled attention processes inhibits pulse processing. This is in accordance to both protective of processing theory, and sensory gating theory. Thus, both theories can explain how short lead interval inhibits, and long lead interval facilitates, the startle reflex. However, Elden and Flaten (2002, 2003) argue that short SOA at 30 - 90 ms, increase PPI due to preparatory attention.

Preparatory attention is directed at a predictable upcoming event, and makes information processing more efficient with anticipation (Bastiansen, Koen & Brunia , 2001), i.e. if a prepulse is not present, the anticipation of the prepulse might alter and inhibit the pulse. In this way, controlled attention may modulate automatic processing of prepulse.

The aim of this study is to investigate how attentional resources are reduced in the elderly by using the paradigm of PPI. In elderly, several theories state that increasing age reduces cognitive resources compared to young adults (Lezak, 1995). By use of "Protection of processing theory" (Graham, 1975), we have a background to understand how PPI is processed in the brain. Elden & Flaten (2002) investigated how automatic processing differ between young subjects when they did a task, compared to a no- task. In this study, by following the same procedure as Elden & Flaten (2002), we assume that the young group will display similar results as their experiment. For the elderly, we expect to see if they display the same results as the young when it comes to attentional resources in task versus no-task. Ellwanger et al. (2003) found no difference between the elderly and the young. We assume that the elderly will display increased PPI on task trials compared to no- task trials. By following rationale of automatic versus controlled attention, we assume that the elderly will display decreased PPI processing on SOA between 120 – 2000 ms. This is based on prediction that cognitive aging have compromised the resources available to task in the elderly, and the necessary resources to accomplish task will be reduced. As a consequence, the startle will be more inhibited in the elderly compared to the young

In no-task we assume that there should be no difference between the elderly and young subjects, in line with Ellwanger et al. (2003). By using cognitive neuropsychological screening test, we assure that none of the elderly have reduced cognitive capacity on a diagnostic level.

Methods

Participants

There were a total of 41 participants, 21 elderly (≥65 years) and 20 young (≤ 40 years). In the elderly, 3 males and 3 females was withdrawn from the dataset due to insufficient responses, leaving 7 males and 8 females (age range 67-88, mean 76 years, mean education 8,6 years). In the young, 1 male and 2 females was withdrawn from dataset due to insufficient responses, leaving 6 males and 11 females (age range 21-28, mean 24,8 years, mean education 17,4 years). 2 elderly participants withdraw from the study due to unpleasure to the noise. In the elderly group the participants were recruited from “de tre nonner” (a café elderly usually attend to), Laureng Center for the elderly, Heracleum Housing– and Service-center for the elderly in Tromsø, and advertisement in local newspaper. The young subject were students at the University of Tromsø.

Hearing of the elderly was tested before the experiment, with a auditory threshold of 40 dB in both ears. The young participants had auditory threshold of 25 dB in both ears.

To rule out dementia, the elderly were tested with Mini Mental State Examination (MMSE)(Folstein, Folstein & McHugh, 1975), Logical History part I and II, and Visual Recognition part I and II, both part of Wechlers Memory Scale- Revisited (WMS-R)(Wechsler, 1987). These test give an overall impression of verbal and visual memory. MMSE is common in Geriatric psychiatry as a rough screening for dementia among elderly. To rule out psychiatric symptoms, a Norwegian version of NeuroPsychiatric Inventory (NPI) were used (Cummings et. al. 1994).

The participants were treated in accordance with the “Ethical Principles of Psychologist and Code of Conduct” of the American Psychological Association (1992). The research was approved by the Medical Research Ethics in Health Region IV in Norway (Project number 52/2006). Participants were given a gift cheque of 100 NOK (about 15 USD) for their participation. This sum was not contingent on their performance.

Apparatus And Stimuli

The experiment took place in an electrically and acoustic shielded chamber with constant temperature at 20 ± 1,5°C. Controll of the experiment and data acquisition was done via a Keithley 575 interface. All programs for experimental control and data scoring was written in ASYST 3,1 by Flaten (Svartdal & Flaten, 1993)

The startle- eliciting stimulus was a 50 ms duration 103 dB SPL burst of white noise with instantaneous rise time, produced by a Coulburn S81-02 noise generator. The output was passed to a Coulbourn S77-06 multiplier/divider and then to a Coulbourn S78-03 linear summing amplifier. The output was sent to a Cambridge Audio (azur 340A) intergrated stereo amplifier and to a pair of Sennheiser earphones.

The comparison stimuli and the prepulse were 70 dB 1000 Hz tones generated by a Coulbourn Signal generator (S81-86) and gated to a Coulbourn S84-04 rise/fall gate. The signal then entered a Coulbourn Linear summing amplifier, then the CambridgeAudio intergrated amplifier, and finally the earphones.

The duration of the prepulse was 30, 60, 120, 240 and 2000 ms, while the duration of the associated comparison stimulus was 20 or 40, 100 or 140, 220 or 260, and 1980 or 2020 ms, respectively. Prepulse duration was the same as the SOA on each and every prepulse trial.

The equipment used for the hearing test was a Grason-Stadler GSI 17 Audiometer (accuracy ± 3%).

Eyeblink electromyographic (EMG) responses were recorded from from the left orbicularis Oculi with Ag/AgCl Sensor Medics miniature electrodes (2 mm diameter) filled with Ultra Phonic conductivity gel. The EMG signal was amplified with a factor of 60000 and filtered (passing 90- 250 Hz) by a Coulbourn S75-01 bioamplifier. The signal was rectified and integrated by a Coulbourn S76-01 contour-following integrator with a 10 ms time constant, and the output was sent to the computer via the Keithley interface. Sampling on each trial began 200 ms prior to onset of the startle stimulus. The sampling rate was 10 Hz prior to onset of the first stimulus and 1000 Hz after noise onset.

Procedure

After giving written informed consent, all participants received a hearing test. Before entering the shielded chamber, the elderly group was examined on their memory function according to each test individual test instructions. The young and the elderly participants were seated in a chair with headrest support placed in a sound shielded chamber (background noise < 25 dB SPL). Before electrode placement, the skin was cleaned with pads containing alcohol and pumice. Two electrodes were attached about 10-15 mm below the pupil and about 15-20 mm below the outer cantus of the left eye. A ground electrode was placed on the forehead. The participants were asked to remain as still as possible and keep their eyes open during the experiment.

The design was a task and no-task for both the young and the elderly group. The participant was equally and randomly presented with task in the beginning, and other half of participants were presented with no-task in the beginning.

In the no-task condition, participants did not receive any instruction except to keep their eyes open and relax. The same program as task was used in no-task procedure.
In task condition, the participant was instructed to judge the duration of a prepulse compared to the duration of a comparison stimuli presented 2500 ms before the prepulse. They were informed the following before entering the experiment:
“You will now hear some tones. You are gone tell me whether the second tone is shorter or longer than the first tone. This is difficult, and you have to choose longer or shorter. When

you have made up your mind, you say out loud and clear “shorter” or “longer”. As told, you are to judge the length of the tones. You shall not pay attention to the scratches you hear. Any questions? Okay, then we start.”.

Participant then responded orally whether the prepulse was shorter or longer than the comparison stimulus. The lab assistant marked on a paper whether the participant was responding to the correct trial, by comparing the trials with the computer program. The SOA between the prepulse and the startle stimulus were 30, 60, 120, 240, and 2000 ms. During the experiment each of the six SOAs was presented 12 times. The startle- eliciting stimulus was also presented alone 6 times. Thus a total of 66 trials were presented. The comparison stimulus was shorter than the prepulse in 36 trials, and longer than the prepulse in the other 36 trials. The intertrial interval varied randomly between 12 and 24 s (average 18 s). In order to ensure a random presentation of the SOAs and the control condition, the seven conditions were presented in 12 blocks, one trial for each condition of each block. After the completion of the experiment the electrodes were removed. The duration for the young group was approximately 40 minutes, and for the elderly approximately 1 hour 30 minutes, including the memory tests.

Datareduction And Analysis

Each reflex was scored 20 – 120 ms after onset of startle stimulus. Baseline EMG was computed as the mean voltage recorded for the last 200 ms before startle stimulus presentation. Response amplitude was the maximum difference between baseline EMG and peak. On trial where no response could be detected, a response amplitude of 0 was scored. The 12 trials for each of the seven conditions were expressed as two blocks of six trials each. Only trials on witch a response could be detected were used in the latency analysis. Prepulse inhibition was calculated as the ratio of reflex amplitude on prepulse trials to startle stimulus alone trials ([prepulse trials]) / ([startle alone trials]). A ratio of 1 meant that no modulation of the startle reflex took place, whereas a ratio of less than 1 meant that the reflex was inhibited. This method of calculating PPI – hereafter called %PPI, is less dependent on differences in control reflex amplitudes than PPI expressed, say as the difference scores between control and prepulse trials (Blumenthal, Elden & Flaten, 2004). This was especially important in the present experiment as reflexes were reliably smaller in the group of elderly subjects (see Figure 1).

Design And Statistics

The design for the %PPI data was a 2 age (young and elderly) x 2 task (Task and No-Task) x 5 SOA (30 – 2000 ms SOAs) mixed design. ANOVA was used to analyse relationship between %PPI and task performance. Analysis for trend was performed for better representation of groups. Young and elderly group was categorized according to “correct” or “incorrect” judgment of prepulse duration. The data were analyzed by the use of STATISTISCA (Statsoft). Post-hoc analyses were performed with the Newman-Keuls test.

Results

Startle Reflex Alone

There were significantly ($F(1, 30) = 6{,}71$, $p = 0{,}014$) increased reflexes in young compared to elderly subject to startle eliciting stimuli alone. Figure 1 displays startle amplitudes acoss SOAs.

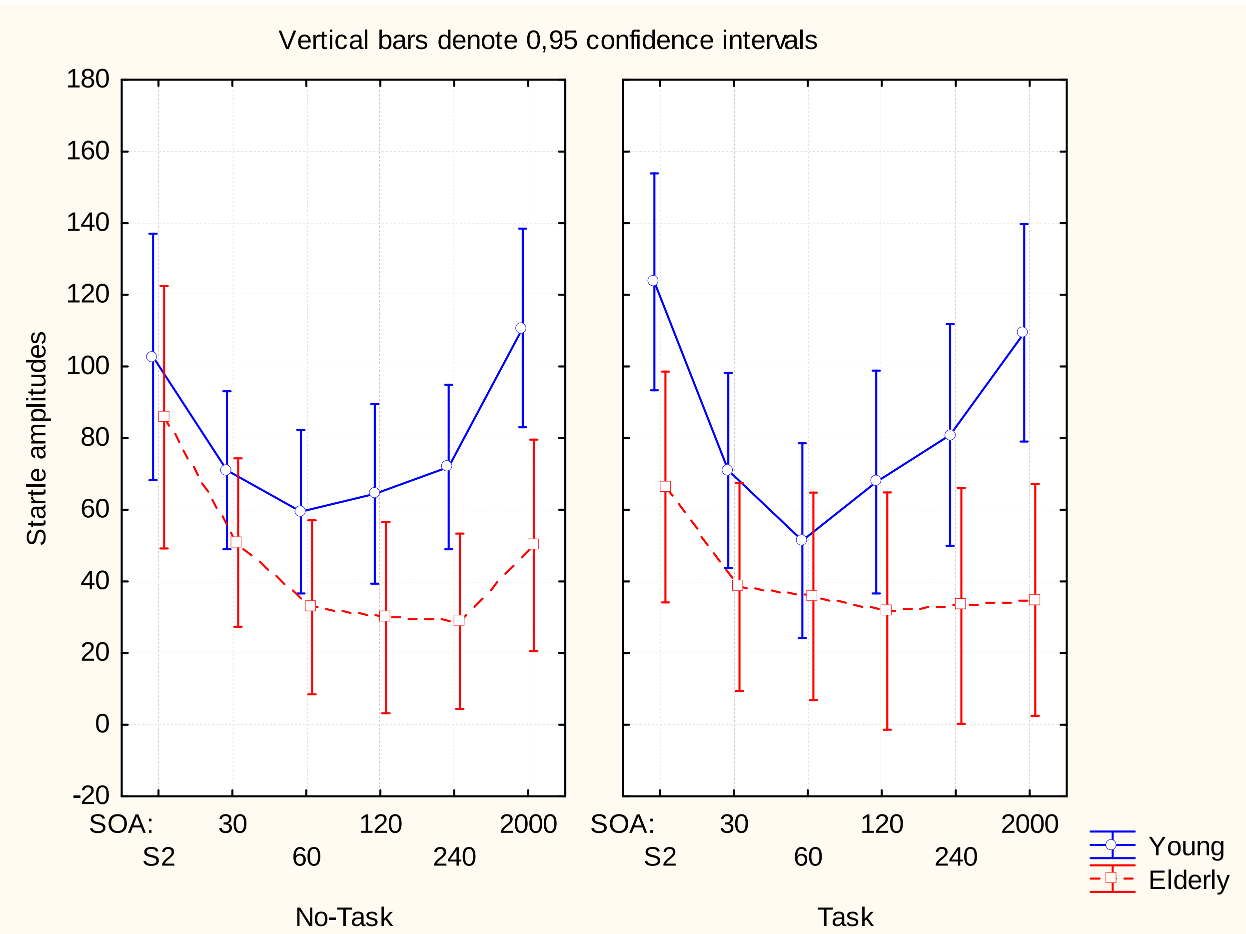

Figure 1: Mean PPI across SOAs in the two age groups as a function of Task. Startle is expressed as amplitudes in A/D-units.

Prepulse Inhibition Expressed In Startle Amplitudes

Prepulse inhibition was reliably seen in both young and elderly subjects: Young subjects displayed decreased reflexes at the 30, 60, 120, and 240 ms SOA compared to startle alone (Fs (1,30) > 7.79, ps < .01). Elderly subjects displayed decreased reflexes at all SOAs compared to startle alone (Fs(1,30) > 5.27, ps < .03) (see figure 1).

%PPI

There was a significant main effect of SOA indicating that the prepulse inhibited the startle reflex. (F (4,120) = 5.44, p < .001). The main effect of task was not significant (F(1, 30) = 2.21, p = .15).

Previous studies have shown an effect of task on startle, and to investigate the effect of Task further, contrasts were computed at each SOA for each age group. There was a significant effect of task for the young subjects at the SOA 2000 ms (F (1, 30) = 5,59, p = 0,025). In the elderly participants, there was no significant difference between the task and no-task conditions at any SOA. The data can be seen in figure 2. No other main effect or interactions were significant.

Visual inspection of Figure 2 indicates that the SOAs did not seem to modulate startle in the elderly. This is different from the usual modulation seen in young subjects, with maximum PPI at about 90 to 150 ms. To further investigate the modulatory effect of the SOA on startle, trend analyses were performed for the task and no-task conditions in young and elderly subjects.

Trend analyses during task for young people revealed a significant linear (F (1, 30) = 8,62, p = 0,007) and quadratic trend (F (1, 30) = 7,42, p = 0,011). In the no-task condition, the young again displayed significant linear (F (1, 30) = 6,60, p = 0,016) and quadratic (F (1, 30) = 7,52, p = 0,011) trends.

In the elderly, on the other hand, no significant trends were seen during task and no-task for both linear (F (1, 30) = 1,2, p = 0,29) and quadratic trends (F (1, 30) = 3,90, p = 0,058).

Prepulse Identification

There was an overall identification between young and old on 54%. The young participants had accuracy on 61% (range 35% to 71%). The old participants had accuracy on 47% (range 10% to 66%). “Correct trials did not significant increase %PPI (F<1), though most correlations are negative, slightly suggesting that "Correct" trials are associated with better %PPI.

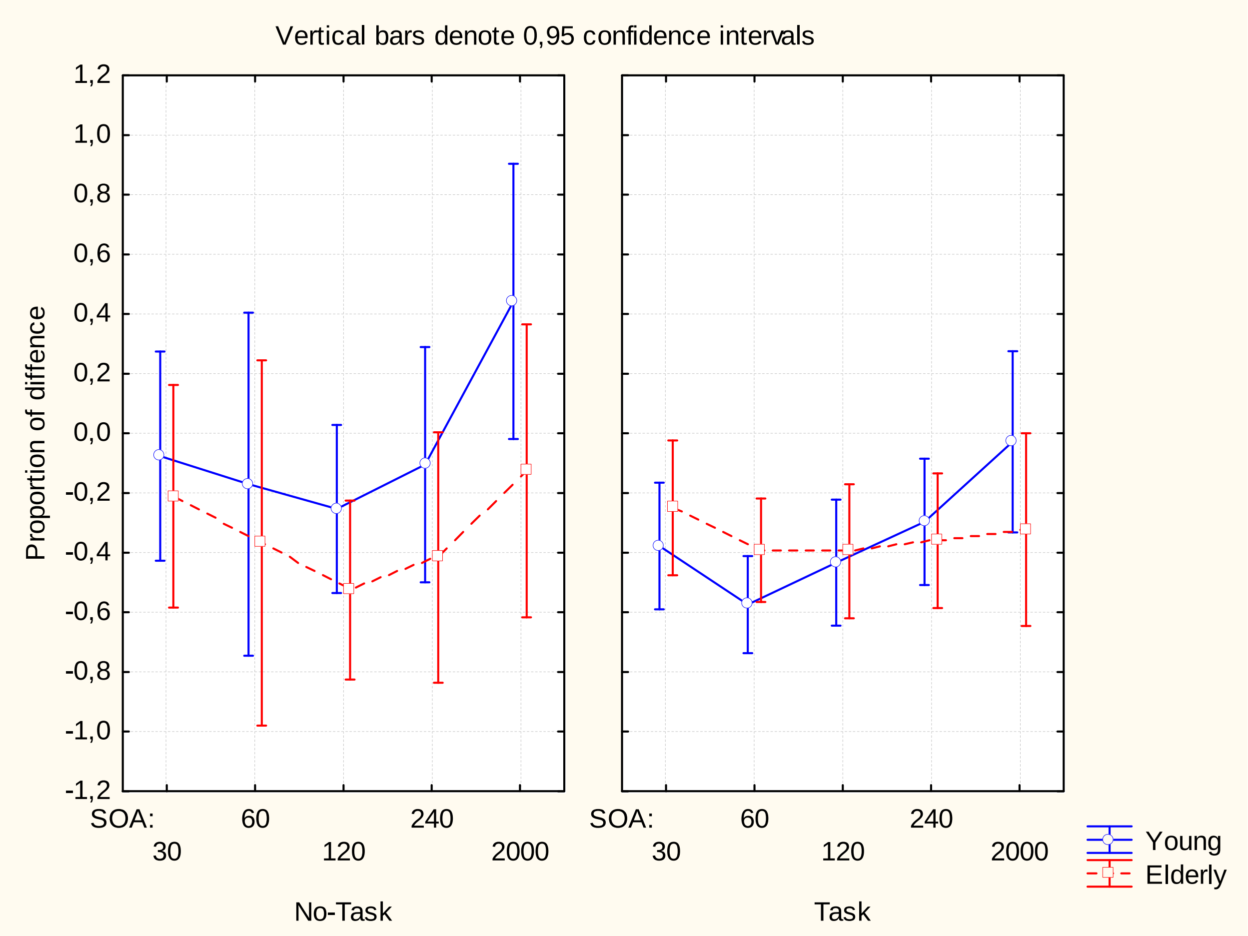

Figure 2: Mean PPI across SOAs in the two age groups as a function of Task. Mean PPI is expressed as proportion of difference from startle alone. Values below indicates PPI, values above 0 indicates facilitation of startle by the prepulse.

Discussion

In the present study we predicted that elderly subjects should show a decrease in PPI compared to young participants in the task, but not the no-task condition. We further predicted that the elderly would show less PPI processing on SOA between 120 – 2000 ms, based on prediction that elderly would have compromised cognitive resources, especially in selective attention.

The main findings were that the young group did better than the old group when it comes to the attentional task. Better performance should be correlated with more %PPI. There was, however, not significantly increased %PPI in the young compared to the elderly group in any condition. Further investigation by trend analysis, reveal that the young have significant linear and quadratic trend in both task and no-task. The elderly had no significant trend during task and no-task, though no modulation on SOAs is present, a result we can interpret as a straight line.

Neither the young nor the elderly had any difference in %PPI related to correct answer in the task. There were no significant correlations between %PPI and percent correct on the task, although most correlations were negative, slightly suggesting that better task performance was associated with increased %PPI. We did not find any effect on neuropsychological examination and %PPI.

Young Participants

Trend analyses supported the conclusion that the SOA differentially modulated startle in young and elderly subjects, with young subjects displaying the often found hyperbolic or quadratic (Fillion, 1998) function with maximal %PPI resources allocated at 90-150 ms (Ellwanger et al., 2003). Thus, less resources are allocated after the initial automatic processing elicited by the stimulus. This is in accordance with previous findings (Elden & Flaten, 2002, 2003), stating that directing attention toward a prepulse is increasing %PPI.

Our results in the young show an increase of %PPI in 30 and 60 ms SOA in task, with a decrease in subsequent SOA. Performance in no-task shows an increase in 30 – 120 ms SOA, with decrease in subsequent SOA. This is in accordance with the results obtained by Elden & Flaten (2002, 2003), that task increase %PPI. Ellwanger et al. (2003) used only 30 and 120 ms SOA and found that SOA 120 ms were associated with increased PPI compared to SOA 30 ms. They did not use task, and didn't include other SOA values than mentioned.

Elden & Flaten (2002) did two experiments. By comparing to startle, experiment 2 found different results in Task, showing that %PPI increased in 120 ms SOA. In three later experiments, Elden & Flaten (2003) supported increase in SOA 120 ms (experiment 1 and 3) compared to startle alone when attending to task. In experiment 2, they reported prepulse facilitation in task at SOA 120 ms, though the participants attended to tactile prepulse.

In sum, our results show a decrease in SOA 60 ms with facilitation in SOA 120 ms attending to task. In no-task we found decreased SOA 120 ms with facilitation in SOA 240 ms, both compared to startle alone. Results in task are in accordance with experiment 2 from Elden & Flaten (2003), though we didn't use a tactile prepulse. Dawson et al (1997) found that when subjects are instructed to attend to acoustic prepulse, automatic processes may be near to 120 ms SOA. Furthermore, they reported an increased PPI at SOA of 120 ms, and suggested that automatic processes attend at SOA up to 120 ms.

Increase in SOA on 30 and 60 ms, might be due to aspect of controlled attention. Elden & Flaten (2002, 2003) argue that since SOA 30 and 60 ms increase %PPI in task, this value is due to preparatory attention, a form of controlled attention that modifies automatic processes. Participants use preparatory attention to mobilize additional resources, waiting for a stimulus to occur, and paying attention to the location of that stimulus. According to Young, Triggs, Pendergaust & Heilman (2000), this generates faster reaction times.

There was a significant difference between task and no-task at 2000 ms SOA. This indicates that prepulse at 2000 ms is further analyzed, in accordance with theory of controlled processing and long lead interval effect (Dawson et al., 1997; Fillion et al., 1998).
Several former experiments show facilitation at SOA 2000. Schell et al. (1995) and Fillion, Dawson & Schell (1993, 1994) report inhibition when following the -attend -task rather than the -ignore -task in SOA 2000 ms. In their experiment, (Schell et al., 1995) the participants had to separate tones of 5 and 7 seconds in duration with a certain pitch, and to ignore tones with a different pitch. They demonstrated that participants had startle facilitation at 2000 ms during to -be -attended tone. By following the same procedure, Filion et al. (1993, 1994) revealed that to -be -attended and to-be-ignored tones produced startle facilitation at SOA 2000 ms, with a greater facilitation in to –be -attend tones. Jennings et al. (1996) found similar results, that SOA 2000 – 6000 was facilitated doing a Task and a No-Task, with greatest facilitation seen at Task. Similar to our study, they found greater facilitation in young subjects at SOA 2000 in Task compared to No-Task (see figure 2).

Facilitation of reflex has been attributed to reflecting greater allocation of attentional resources to the attended tone. In our experiment, this means that when participants are attending to task, the reflex gets less strength due to controlled attentional processing. Since the reflex strength in task is not like pulse alone, it indicates that attention is working with remaining analyses of the prepulse in addition to analyses of task. This produce a inhibition in SOA 2000 ms. In other words, summation of prepulse and Task demands more on attentional analyses. In No-Task we se smaller facilitation on reflex, due to less demands on attention. Though, our result in SOA 2000 is in accordance with Jennings et al. (1996), that degree of facilitation appear to reflect task difficulty.

Elderly Participants

Figure 2 shows that the elderly didn’t show a normal curve for %PPI. According to previous studies, both animals and humans show an U form in PPI (Ellwanger et al., 2003), indicating most inhibition at 90-150 ms. The elderly in this study did not show maximum

%PPI around 100 ms in this interval, indicating that the modulatory effect of the SOA in the elderly is absent, even if elderly subjects do display significant %PPI over different SOAs. Accordingly, task and no-task have no %PPI modulation at SOA beyond 30 ms, and can be considered to be a joint, straight line. Due to the straight line, it is difficult to separate whether task made a difference in our study. No significant interactions were reported during task at different SOAs. Visual inspection of figure 2 indicates that some modulation takes place from SOA 60 ms and beyond, though no significant results support this observation. Among rodents, Varty et al. (1998) found no relationship of age between PPI or startle when conditioned to auditory stimuli. In humans, former studies investigating task in elderly (Harbin & Berg, 1986), revealed no effect of PPI in an attention demanding visual search task. Thus they found no effect of task. Though, in their study only SOA 120 ms was assessed. Our results indicate no effect of task at SOA 120 ms, similar to Harbin & Berg (1986).

Working Memory And Attention.

Due to the straight line, task and no-task indicates no %PPI modulation at SOA beyond 30 ms. Braff & Geyer (1990) claim a prepulse interval of 30 ms is to brief to evoke attentional mechanism. However, Bastiansen et al. (2001) argue that the anticipation of a prepulse, might inhibit the pulse. Further, Young et al. (2000) claim that preparatory attention generates faster reaction time. Our elderly have a significant difference between startle alone and decreased %PPI at SOA 30 – 2000 ms. Thus, the straight line from 30 ms and beyond, might have been released by preparatory attention. The first prepulse at SOA 30 ms, triggers an attentional analysis. Due to preparatory analysis, reaction time is faster, allocating extra reserves the elderly might have for subsequent analyses. Thus, with aging the necessary resources in selective attention are reduced, leading to problems with inhibitory functions in working memory. Due to these problems, SOA on 30 ms gives the elderly an inhibition on the reflex curve, compared to pulse alone. This is in accordance with Capacity theory (Hasher & Zacks, 1988), stating that reduced inhibitory function in elderly, make processing of SOA values problematic. In line with this, McDowd & Filion (1992) state that since inhibitory mechanism in the elderly have been compromised, they have a deficit in selective attention.

In the subsequent SOAs, the elderly are inhibited to the same degree as in the first SOA. The “capacity theory” (Hasher & Zacks, 1984; Zacks et al., 1996), explain this with a memory capacity decline the elderly suffers from. When the elderly is hearing prepulse and pulse from SOA 30 ms, WM will process the stimuli as an attentional analysis. When a subsequent SOA is presented, attentional capacity is still working with the former stimulus. This processing leaves no "left over" capacity available to process the subsequent incoming stimulus. Thus, for our elderly, the first inhibition from 30 ms SOA does not let go since WM is in constant occupation with a thoroughly analysis. Thus, it seems like SOA 30 ms suffers from an attentional loop that prevents new incoming information.

In sum, the result is constant inhibition, a result we can read as a straight line, implicating that the elderly have no attentional capacity to elaborate SOA between 30 ms to 2000 ms.

In the young, SOA 2000 ms had effect on task, thus PPI is assumed to be under controlled processing (Dawson et al., 1997). In the elderly, the effect from 2000 ms SOA goes for both task and no-task. It might seem like SOA 2000 ms, makes attention capacity in the elderly less occupied by analysis of the first SOA. Though, according to theory of controlled processing and long lead interval effect, prepulse at 2000 ms should allocate greater attentional resources. An elaborated explanation could be that the elderly need more time to analyse prepulse, a result we can see in figure 1 and 2, where the elderly have a delay in measured reflex responses compared to the young. This might be due to ongoing attentional processing in the elderly, i.e, elderly subject seem to process the prepulse for a longer time compared to the young subjects. According to capacity theory (Hasher & Zacks, 1984; Zacks et al., 1996), prepulse suffers from poor encoding of incoming information. Since older adults may have deficient inhibitory mechanism (Zacks et al., 1996), the elderly is unable to quickly remove the information already entered in WM, leading to poor efficiency and long elaboration time, i.e. the first prepulse at SOA 30 ms that already entered WM, is not removed due to inhibition problems. Further, the elderly is unable to receive incoming stimuli since this stimulus will be regarded as irrelevant information, and therefore is denied access to selective attention. Since controlled processing allocate attentional resources, and attention suffers from already entered stimuli in WM, we see increased %PPI in the elderly at 2000 ms after prepulse onset, as confirmed in the trend analyses.

Neurobiology In Elderly.

Peterson et al. (1999, 2001) suggest that there is a transitional state between normal aging and mild dementia. The established boundaries between a dementia diagnose and normal elderly exist in a continuum that is hard to define. Further, that the notion of normal aging is less well understood. Thus, many elderly might suffer from cognitive problems that cover a wide variety, including attention or memory.

How age influence Auditory Startle Response (ASR), was investigated by Koefler, Müller, Reggiani & Valls-Sole (2001). They investigated three age groups, below 30 years, from 30 to 50 years, and above 50 years old. Results revealed that in group three (above 50 years old), there was significantly longer ASR compared to young. They suggest a subclinical age-dependent slowing of peripheral nerve conduction, though this takes place in only 10% in those of 60 years. Further, they claim that other mechanism might explain the results. The EMG responses were delayed in the old compared to the young, something they attribute to age-dependent slowing of central reticular processing (CRP) rather than peripheral nerve conduction slowing. Among CRP, they consider nRPC a central structure in integrating the pattern of ASRs. Situated in caudal brainstem, CRP are distributed up to cranial nerve nucleus and down the spinal cord along reticulospinalis pathways. Further, it receives input from the cochlear nucleus and modulatory inputs from the basal ganglia and cerebral cortex. Thus, for the eyeblink reflex, the oldest participants may exert less cortical inhibitory influence on complex brainstem reflexes than younger subjects.

As a consequene, central reticular slowing might influence startle in the elderly, leading to inhibition in muscle strength on the reflex. In addition, approximate 10 percent of our elderly might have a slowing of peripheral nerve conduction in Orbicularis Oculi.
Flaten and Friborg (2005) found that a decrement in the elderlys ability to acquisition of a Conditioned Response, might be due to reduced Orbicularis Oculi muscle strength.
In sum, these problems might explain the straight line and the subsequent weaker result the elderly have on task and no-task. Our study didn't have any chance to test the muscle strength by itself, though it could explain the lower amplitudes seen in Figure 1.

Studies investigating PPI and progression to dementia (Hejl et al., 2004; Ueki, Goto, Sato, Iso & Morito, 2006), suggest a development from entorhinal cortex to limbic areas in disease progression before a clinical diagnose of dementia is established (DSM-IV, 1994). Hejl et al. (2004) reported that rat studies doing lesions in entorhinal cortex and amygdala, have shown to attenuate PPI. In addition, Limbic areas are suggested to participate in regulation of PPI due to connection to nRPC via Limbic cortico-striato-pallido-pontine. This pathway is connected to globus pallidus, projecting to pedunculopontine tegmental nucleus, which is a direct link to nRPC due to its integral component of the startle reflex pathway (Ueki et al., 2006). In humans, Pissiota et al. (2002) used PET study and confirmed nRPC as startle centre. Further, Entorhinal cortex give rice to widespread pathway representing the major source to hippocampal formation. Hippocampus, amygdala and entorhinal cortex are all structures known to be implicated by dementia and mild AD (Alzheimers Disease), producing deficits in short term memory and working memory (Hejl et al., 2004). Reduction or damage to these areas are closely connected to memory impairment (Lezak, 1995). As a consequence of general aging, and the wide continuum declining cognitive resources lies in, it is possible that the elderly have reduced %PPI due to problems in nRPC and limbic areas. Though, if the elderly have problems in limbic areas, this might explain why WM is influenced since hippocampus most likely is affected together with entorhinal cortex.

Protection of Processing Hypothesis

Our experiment is the first, to our knowledge, to investigate task and PPI in elderly. Earlier research involving elderly, have proven no obvious relationship between elderly and PPI (Ellwanger et al., 2003; Flaten & Powell, 1998; Hejl et al., 2004; Flaten & Friborg, 2005). Common for all these projects is the use of a passive paradigm, whereas we use a task. Harbin & Berg (1986) presented a task and a no-task condition in separate blocks (similar to our study) to both young and elderly. They found that in the young the task increased %PPI, but did not affect startle amplitude to the reflex eliciting stimuli alone. Similar to our study, the elderly had no difference between task and no-task, though their study only investigated SOA of 120 ms.

As stated earlier, it seems that the elderly are continuously attending to the task, producing a continuous inhibition over all SOA values in this study. The straight line goes for both Task and No-task, which only partly support The Protection of Processing Hypothesis (Graham, 1975) or The Sensorimotor Gating hypothesis (Braff & Geyer, 1990). According to them, attending to a task should increase PPI, with a subsequent decrease as time goes by. Our result shows a difference between startle alone and SOA 30 ms, which indicate that some attentional process takes place, according to the theories. Thus, no difference between task and no-task in the different SOAs, and due to no modulation in graph, the theories are insufficient to explain the results in elderly.

The young show difference between task and no-task, and task increase %PPI significant in SOA 2000 ms. Thus, according to Protection of Processing hypothesis (Graham, 1975), doing a task will serve to protect attention from other stimuli, to make sure that the incoming stimuli is analysed and processed thoroughly. Norris and Blumenthal (1995, 1996) found support for the hypothesis among their participants. By doing a judgement task with sounds of different pitches, results revealed that attending to task increased %PPI. Elden & Flaten (2002, 2003) supported these results. They reported that directing attention to task increased %PPI. According to the hypothesis, participants attending to task are protected for incoming pulse, and gives a weaker blink reflex. Though, the authors conclude with support to Protection of Processing hypothesis.

Our results in the young support this statement, since the participant attending to task is occupied in selective attention by analysing prepulse, thus, attending to a task increases the strength on selective attention. Pulse in our study revealed that %PPI is inhibited in Task compared to No-Task, although this was significant only at the 2000 ms SOA. Thus, the young seem to have sufficient capacity to rapidly process the stimuli in selective attention, and be ready for the next stimuli. In addition they show the common form of PPI (see figure 2) with a hyperbolic or quadratic function. The capacity to attentional analyses might be explained by young age and education, and these factors increase the total cognitive capacity available (Lezak, 1995). In accordance with our hypothesis, results from the young supports the Protection of Processing hypothesis.

Prepulse Identification

Like Elden & Flaten (2002, 2003) and Postma, Kumari, Hines & Grey (2001), our study found no relationship between prepulse identification and PPI. Postma et al. (2001) used 85 dB prepulse and 75 dB continuous background noise. Startle was 116 dB burst. In addition, the task used for the study was easy, compared with the one used by Norris & Blumenthal (1996), where the subject did a task evaluating lights position in a grid. Results show that judging the lead stimuli, increased %PPI.

The hypothesis whether good task performance is related to increased %PPI, are not supported in our results. It might be that the relationship between correct judgments and PPI, as an indicator of selective attention, has pitfalls. The task was difficult. Time and length between the tones in task was short and very similar.

The elderly might have found task more difficult than the young, answering no better than chance on correct trials with correct response of 47%. If the elderly gave answers by chance, the accuracy should be 50%. The lab assistant did experience during performance of experiment, that the elderly didn’t understand how to perform the task and became confused. Previous to the experiment, extra time and consideration was necessary to make sure that the elderly understood the task. In addition, to make the task easier to understand, a sketching including the warning tone, prepulse and pulse was made. Still, it seems that the instructions might have been difficult. An explanation might lie in the extremes the elderly shows compared to the young on age (mean 76) and education (mean 8). In the neuropsychological testes, the elderly scored normal, though no neuropsychological test for attention was included.

The young understood the task at the first instruction. The participants were highly educated (mean 17), which indicate good cognitive capacity (Lezak, 1995), and have the advantage of good capacity due to their young age (mean 27)(Lezak, 1995). Thus, the task might have been easier for this group, supported by an average correct response on 61%. Future studies among elderly and PPI, must take extra care in designing the task procedures.

Background-Noise

Earlier studies concerning elderly and PPI, have made use of continuous background noise (Ellwanger et al.,2003; Hejl et al., 2004, Postman et al., 2001). Common is that the elderly did not reveal any significant effect of age on PPI, similar to our results. In a study by Ellwanger et al. (2003), the greatest PPI was seen in the middle age group, with small PPI in the extreme groups (College group mean 21 years, old group mean 74 years). Their study made use of continuous background noise, that might camouflage the strength of prepulse and the startle releasing stimuli, giving it less strength to release startle reflex with sufficient intensity. Flaten, Nordmark & Elden (2005) found that continuous background noise alter PPI when acoustic prepulse is used. Our study made use of extreme age groups, and no background noise. By not using background noise, signal to noise ratios (i.e., the prepulse to background stimulation levels) are maximal and the prepulse is easily identified, compared to experiments where the signal to noise ratio is lower due to increased background noise. By reducing background to noise levels one would make the task more difficult, and this could have affected the results and increased the difference between the task and no-task conditions in the young. In the elderly, task performance was at chance levels showing that the task was as difficult as it could be, and background noise would not, most likely, affect %PPI in this group of subjects.

Arousal

In addition to background noise, it been claimed that increased inhibition could be due to arousal and alertness (Flaten et al., 2005). Though, Kahneman (1973) state that lack of "fuel" to cognitive processing can be increased by arousal. In our experiment, the results in the young group do not support such a conclusion. Increased arousal increases startle amplitude without affecting startle latency. If arousal was responsible for increased %PPI in Task group, then startle reflex amplitude should be larger in this group. In our study, startle reflex alone is not affected, suggesting that arousal and alertness most likely have no effect on the increase in %PPI. This is in accordance with Elden and Flaten (2002) who found only slightly increased arousal in the task compared to the no-task condition. When it comes to the elderly group, our results suggest no effect of arousal and alertness, though the elderly seems to have a continuous and steady inhibition on all SOAs.

Limitations

There are several limitations in our study. First limitation is that it is to few participants in both the elderly and the young group. This made ANOVA analyses difficult and the study had a reduced Statistic Power. We had to exclude several elderly because of low or insufficient reflexes. Low reflex strength might be due to electrodes or the conductivity gel, giving distorted measurements. Koefler et al. (2001) argue that 10 percent of elderly have age-dependent slowing of peripheral nerve conduction. This might be a contribution in how to explain why we had to exclude several of the elderly. Further, among several of the elderly, aging gave Orbicularis Oculi less texture, making it more difficult to find good connection point for it. A second limitation is that our study didn't use background noise. By using ambient noise, the participants might have been aware of other noise in the room, making their attention being drawn to other sounds than the prepulse. Thus, preparatory attention might have been triggered by a stimuli different from the prepulse and pulse.

Third limitation. Ellwanger et al. (2003) argue that use of extreme groups, common in studies of elderly, is not sufficient since their results indicate most %PPI in middle age group. Our study used only young and elderly, and no middle age group. We therefore lack comparison groups to see whether our results are unique for our elderly.

Last limitation. The age groups were different according to education level. All the young participants were students at the university at a level equally to late Bachelor or Master Level. The elderly rarely had education beyond elementary school. It is well established that education increases cognitive capacity, something that might contribute to explain differences in task condition.

Conclusion

In sum, our result in the young supports The Protection of Processing Hypothesis. By attending to task, we see an increase in PPI across SOAs, most probably to attentional processing. The elderly partly support Protection of Processing Hypothesis since 30 ms SOA gives a modulation compared to startle alone. The subsequent SOAs show no modulation compared to 30 ms, giving a “straight” line curve. Protection of Processing is insufficient to explain this result. Due to constant occupation in attentional working memory, the elderly lacks the capacity to process and elaborate incoming information beyond 30 ms SOA. Inhibition problems also prohibit new incoming information to enter WM. The elderly experience inhibition problems that give them no attentional capacity to elaborate SOA 30 – 2000 ms. Preparatory attention might participate in the use of attentional resources, adding up on the attentional demands already established by prepulse. Physiological changes in the cortex, due to aging, might contribute to problems in selective attention.

All over, this lead to degraded processing capacity in the elderly to subsequent analyses following the first prepulse and pulse. Thus, investigation in elderly, %PPI and cognitive analyses of stimuli is recommended. Further, there is a need to know more precisely how and at what point the elderly experience inhibition problems.

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