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Running head: ANXIETY AND DIVIDED ATTENTION IN YOUNGER AND OLDER ADULTS

Divided attention in older but not younger adults is impaired by anxiety.

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Abstract

It has been hypothesized that the disruptive effects of negative emotional states, such as anxiety and depression, may contribute to poorer performance in older age (Yesavage et al., 1988; Deptula et al., 1993). Some studies have reported that higher levels of anxiety are associated with poorer cognitive performance in older adults but not younger adults (Cohen, 1980; Deptula, 1993, but see Jennings et al., 1989). We examined if age and anxiety interact with performance by comparing the performance of normal healthy younger and older adults on cognitive and motor tests under conditions of selective and divided attention. Ninety-two older adults (Mean age = 70.1 years, SD = 7.1) and 78 younger adults (Mean age = 18.8 years, SD = 1.9) matched on education, vocabulary, and self-reported health performed a word comparison and pursuit-rotor task under conditions of selective and divided attention. Anxiety was assessed using the Speilberger State-Trait anxiety scale (Speilberger, 1983). The hypothesis was supported: higher anxiety was associated with poorer divided attention performance in older – but not younger adults. Anxiety was not associated with poorer motor performance in older adults. Implications of the results for cognitive-resource theories of aging cognition are discussed.

Age-related decline in cognitive performance has been attributed to a number of factors including central nervous system (CNS) degeneration, decline in processing speed and attentional abilities, and lack of practice in performing cognitive tasks (cf. Salthouse 1994 for a review). It has also been hypothesized that the disruptive effects of negative emotional states, such as anxiety and depression, may contribute to poorer performance in older age (Yesavage et al, 1988; Deptula, 1993). Research suggests that anxiety and depression are often associated with impairment in memory (Henry et al, 1973; Depulta et al., 1991) and other cognitive functions (Knox et al, 1970; Gur et al, 1988), although under certain circumstances anxiety may facilitate performance (Spielberger, 1962). In a review of the effects of anxiety on performance, Humphreys & Revelle (1984) suggest that high anxiety can facilitate performance on easy tasks or when the feedback is positive, but can hinder performance on difficult tasks or when the feedback is negative. While the relation between anxiety and performance on cognitive tasks has been well studied in the young, there are relatively few studies on this topic among older persons, and even fewer studies that have compared younger and older groups.

Cohen et al. (1980) reported that whereas high trait anxiety was associated with augmentation of performance in younger subjects on a test of reasoning, higher levels of trait anxiety were associated with poorer performance on the same test in an older group. Cohen concluded that older persons may be more vulnerable than the young to the deleterious effects of ‘negative’ emotional states on performance.

Deptula et al. (1993) examined the relation between emotional states (self-rated depression, anxiety, and withdrawal) and performance on a memory task in groups of normal young adults and normal older individuals. It was hypothesized that the older would exhibit a stronger relation between ratings of negative emotional states and performance than the young adults, and that the older would have a steeper drop-off in performance associated with increasing levels of such negative emotions. Results indicated that the older group, but not the younger group, consistently exhibited significant negative correlations between their performance on verbal recall measures and their ratings of anxiety, depression, and withdrawal. On the basis of these results, Deptula et al. concluded that negative affect modulates the relation between aging and memory functions. It remains unclear how this modulation might take place. For example a study by Jennings, Brock and Nebes (1989) suggests that the arousal component of anxiety does not mediate the relationship between age and performance. Younger and older adults were assessed using self-report measures of arousal and stress between trials and cardiovascular measures of arousal during trials on a divided attention task (i.e., add four successively presented numbers, while simultaneously responding to the random presentation of a two-choice LED display) under conditions of noise or quiet. The authors concluded that neither self-report not cardiovascular change unequivocally supported the view that general arousal induced the performance changes associated with noise or aging. In a follow-up study that assessed the energetic demands while performing an episodic memory task as memory load was increased and as a single task and as a dual task that added simple reaction time (RT) stimuli, Jennings, Nebes, & Yovetich (1990) found that when compared to younger men, older men showed an increased heart rate during the maintenance of high versus low memory-load items. Furthermore, older adults who did poorly appeared to focus on the maintenance of memory to the exclusion of the RT task and they also showed more acceleratory changes during memory maintenance than did those who did better. These results suggest the possibility that older adults may attempt to compensate for an age-related decline in memory performance as task difficulty increases by increasing task-relevant arousal allocation.

On the other hand, environmentally induced increases in arousal level may disrupt the performance of older adults. Backman & Molander (1991) examined the performance of younger and older skilled miniature golf players during training and competition. Both younger and older adults showed a similar increase in heart rate and self-reported anxiety, but while younger adults improved performance during competitive play, the performance of older adults deteriorated. Backman & Molander conclude that their findings are consistent with suggestions that older adults are less able to cope with high arousal conditions than are younger adults as a result of age-related deficits in task-relevant cognitive abilites.

Depulta et al. (1993) proposed a causal mechanism whereby anxiety mediates memory performance in older adults. They state that anxiety is composed of two conceptually distinct components, worry and emotionality (Eysenck, 1979), and suggest that it is the cognitive component of anxiety - worry - which interferes with performance by diverting some of the brain’s processing capacity to task-irrelevant information (see Sarason, 1984). Furthermore, they suggest that anxious individuals attempt to compensate for this with an increase in effort and that older adults have less reserve capacity to compensate for the adverse effects of anxiety on memory than the young.

Studies with younger adults have found a consistent interaction in impaired performance in high trait and/or test anxious individuals and task difficulty (see, Eysenck, 1982 and Mueller, 1992 for reviews). Mueller notes that the increased distractibility that occurs when anxiety increases is a likely result for complex tasks, whereas for simple tasks increased anxiety would have either no effect or perhaps yield some benefit (reduced distractibility). Eysenck (1992) proposed that if high and low-anxious groups perform a central task at an equivalent level, it is assumed that the high-anxious group has achieved this by investing more processing resources than the low-anxious group. If the presence of a load task prevents extra resources from being allocated to the central task, then the performance of high-anxious individuals should be impaired (see Eysenck, 1992 for a review of relevant studies).

Studies comparing the performances of younger and older adults have consistently observed that increasing task complexity leads to greater declines in performance in older relative to younger individuals in many different information processing situations (Cerella, 1991; Myerson and Hale, 1993). This phenomenon, known as ‘the complexity effect’, is often explained in terms of age-related declines in speed of processing (Salthouse, 1994) and used as evidence to support a general slowing model of aging cognition (Salthouse & Verhaeghen, 1997).

In the current study, the question was whether age-related complexity effects are mediated by anxiety. Assuming that it is the cognitive component of anxiety - worry - which interferes with performance by diverting some of the brain’s processing capacity to task-irrelevant information (Deptula, 1993; Sarason, 1984), it might be expected that the deleterious effects of high anxiety as task complexity increases would be larger for tasks with a significant cognitive component. Therefore, we tested younger and older adults on both cognitive (i.e., word comparison) and non-cognitive (i.e., pursuit-rotor) performance tasks to examine the differential effects of high anxiety as task complexity was increased.

Two main predictions were made in the current study. Firstly, the prediction was that the negative effects of high anxiety on performance as task complexity is increased would be more pronounced for older adults in general as they have less reserve capacity to compensate for the negative effects of anxiety (Deptula et al., 1993). Specifically, a significant age-group x task complexity level x anxiety level interaction effect was predicted. The second prediction was that the negative effects of high anxiety in older adults would be larger for cognitive than for non-cognitive tasks i.e., an age-group x anxiety-level x task-type interaction effect.

Definitions of task 'difficulty', 'complexity', and 'load' are not always clearly distinguished in the cognitive aging and anxiety-performance literature (see McDowd & Craik 1988; Crossley & Hiscock, 1992; Eysenck, 1992). Task complexity was manipulated in this study using the single/dual task paradigm. According to McDowd and Craik (1988) the division of attention is one of several equivalent ways to increase overall task complexity (see Eysenck, 1992 for a discussion). Depending on specific processing requirements, any task complexity manipulation is likely to be influenced by a different combination of bottom-up (e.g., processing speed) and top-down (e.g., inhibitory control/task co-ordination) mechanisms (see Kramer et al., 1995), each of which may be altered in specific ways by the effects of aging and anxiety. Furthermore, depending on how specific processes are defined, other task complexity manipulations (e.g., increasing the number of response alternatives) may interact with aging and divided-attention performance in complex ways (see McDowd & Craik, 1988).

In the current study, participants were exposed to seven different experimental conditions (3 cognitive and 4 motor). In the word-pair comparison task participants were required to make a lexical decision, a semantic decision, and both a lexical and semantic decision concurrently. In the pursuit-rotor tracking task participants tracked a target with the right hand at two speeds (slow and fast) with or without the simultaneous requirement to use their other hand to perform a secondary task. While the manipulation of single/dual task demands in the cognitive and motor tasks were not identical, the current study allowed for an analysis of the interaction between age, anxiety and divided-attention in both cognitive and motor performance domains.

Method

Participants

Participants aged 60 years and older were recruited from five organizations for retirees. Exclusion criteria included not being right-handed, not currently living independently in the community, or suffering from any medical conditions associated with a head injury, limb injury, spinal injury, stroke or heart attack. Of approximately 200 persons invited to participate, 94 agreed. Reasons for non-participation included being too busy or not interested. The younger sample consisted of 78 undergraduate psychology students (Mean age = 18.8 years, SD = 1.9, 30 males and 48 females)

The number of years formal education was significantly longer (df = 168, t = 2.9, p = .004) in the younger group (mean = 13.9, SD = 0.8) than the older adult group (mean = 13.1, SD = 2.6). However, on comparison of younger (mean = 62.8, SD = 7.1) and older (mean = 67.8, SD = 9.7) Wechsler vocabulary scores (Wechsler, 1971), a marker test from the broad crystalized domain or the cognitive pragmatics, the older adults were found to have significantly higher scores (df = 167, t = - 3.9, p = .0001). Self-rated health, assessed using a 5-point likert scale was similar for both age-groups (younger: mean = 2.9, SD = 0.8; older, mean = 3.1, SD = 0.6). As the use of medications is common amongst individuals aged 60 years and over, participants who were required to take medications were not excluded from the sample. However, as the use of certain medications may be expected to affect performance, all participants were asked to report the use of the following medications: sedatives/hypnotics, tranquilizers, antidepressents, diuretics, antihypertensives, cardiac medications and anti-inflammatory medications. Nine younger and 46 older participants reported taking one or more such medications daily. Medication use did not have any significant effect on the results of analyses conducted below and will not be discussed further here. Corrected visual acuity was assessed using a Snellen chart on first arrival in the testing room. Corrected 20:30 vision or better was required for participants to be accepted in to the study which resulted in two older participants being excluded. This reduced the sample of older adults to 92 (Mean age = 70.1 years, SD = 7.1, 43 males and 49 females)

After informed consent had been obtained, an appointment with each participant was arranged. The test battery took approximately 60 to 90 minutes to complete.

Experimental tasks

Word comparison tasks

Each participant was seated with head stabilised on a chin rest placed 18 inches from the centre of the computer screen and was given the instruction to focus on the centre of the screen (marked with an 'X'). Central fixation was maintained for a randomly varied interval of 1 to 3 seconds between successive trials. The stimuli were presented in the 40-column text mode on a Commodore 1930 color video monitor. Standard instructions for each task were displayed on screen and responses were made using designated keys on the computer board. Unless otherwise stated, the right hand was used to press response keys in the tasks described below. The instructions stressed that each response should be as fast and accurate as possible. A trial run, consisting of 10 trials, was given prior to each task to familiarise the participant with the task. Trials on which RT was less than 150ms or 3 SD above the mean for task conditions were eliminated automatically. Median reaction time (RT), RT standard deviation (SD) and errors were recorded for each participant in each condition described below. Error trials were excluded from the calculation of medians and standard deviations.

The word comparison task had three experimental conditions. In each experimental condition two words were presented on the screen simultaneously. Words presented in each experimental condition were identical. Four high frequency words, in everyday usage, were chosen from each of the categories: (a) Furniture (Table, Chair, Lamp, Bed), (b) Body parts (Head, Hand, Leg, Arm), and (c) Animals (Horse, Dog, Cat, Snake). Also, keypad responses for each experimental condition were identical, i.e., participants held their index and middle fingers above the keys ‘1’ and ‘2’ respectively on the lower right hand side of the keypad. The three experimental conditions differed only in the cognitive demands required for word comparisons. In all three experimental conditions, word pairs remained on the screen until a response was made. Each experimental condition consisted of 50 trials.

Identity matching condition

Participants were presented with a word pair (e.g., Dog : Table, or Dog : Dog) and asked to decide as fast as possible whether the two words were identical or not. The probability of words being identical or different was equal. The participants were instructed to respond as quickly and accurately as possible by pressing “1” if both words presented appeared the same, and “2” if the words differed in any way.

Semantic comparison.

Participants were presented with a word pair (e.g., Dog: House, or Dog: Cat) and asked to decide as fast as possible whether the two words were from the same categories or not. The computer programme was designed to randomly select any word from the 3 semantic categories and match it on 50% of trials with a word from the same semantic category, and on the other 50% of trials with a word from a different semantic category. Participants were instructed to respond as quickly and accurately as possible by pressing "1" if both words presented came from the same semantic category, and "2" if the words were from two distinct categories.

Dual task comparisons

Participants were presented with a word pair (e.g., Dog : House, Dog : Dog) and were instructed to make two decisions in quick succession. Firstly participants had to decide as fast as possible whether the two words were from identical semantic categories or not. This part of the test was identical to the semantic comparison test above. In addition, participants had to decide as fast and accurately as possible whether either word in the pair had the letter "a" in it or not. Participants were instructed that the speed and accuracy of both responses was equally important. These instructions were designed to divide attention equally to both tasks. With their right hands participants first judged on semantic similarity as before by pressing either "1" or "2". After they had made this decision participants were asked to orally report as fast as possible (by saying 'yes' or 'no') whether or not the letter "a" appeared in either of the two words on the screen. The word pair remained on screen until both decisions had been made. Pilot research had revealed that this task proved difficult for both younger and older adults and significantly slowed semantic decision times without having a significant effect on errors. This divided attention effect was confirmed in the current study (see Results section).

Pursuit-rotor tracking task

The pursuit-rotor apparatus (Electronic developments, Hampton, Model JN-587) comprises a revolving disc and a hand-held stylus used to track it. The amount of time the stylus remains in contact with the small circular metal stud on the turntable is recorded automatically by a counter. Unimanual and bimanual tracking performance was testing at two different pursuit-rotor speeds (.25 and .5 rev/sec). Age differences in pursuit tracking in both unimanual and bimanual conditions have been reliably observed in previous studies (Proteau et al., 1994; Pratt et al., 1994; Moes et al., 1995).

Pursuit tracking performance was assessed under 4 experimental conditions. In all four conditions participants were instructed to hold the pursuit-rotor stylus in their right hand and to keep the stylus on the revolving metal disc. Thirty seconds practice was given prior to each experimental condition. Experimental conditions lasted for 30 seconds and rest breaks were provided between each practice and experimental condition.

Unimanual tracking was assessed under 2 experimental conditions: at pursuit speeds of .25 rev/sec (condition 1) and .5 rev/sec (condition 2), respectively. In the bimanual tracking conditions participants were instructed to track the pursuit-rotor disk with the stylus held in the right hand while also tapping a single beat by alternating between two drums with the left hand. Bimanual tracking also was assessed under 2 experimental conditions: at pursuit speeds of .25 rev/sec (condition 3) and .5 rev/sec (condition 4), respectively. In order to avoid an imbalance in dual task trade-off functions (Eysenck, 1992) participants were monitored during both practice and experimental trials to ensure that bimanual drum tapping was consistently maintained and at a rate that was at least 60% of their maximum unimanual tapping speed. Pilot studies revealed that with adequate instruction both younger and older adults were able to maintain a consistent tapping movement with left hand that remained within 50 – 70% of the maximum tapping speeds while tracking the pursuit-rotor target with the right hand. Therefore, the current study focuses on the decrements in pursuit tracking performance associated with the four experimental conditions outlined above.

Anxiety:

Anxiety was measured using the State-Trait Anxiety Inventory form Y (Spielberger, 1983). A 40-item self-report scale consisting of 20 questions which assess current anxiety (state anxiety), and 20 questions which assess anxiety in general (trait anxiety). Both state and trait scores were used in the current study.

Procedure

Experimental sessions began with participants being asked to fill out a demographic questionnaire that included questions regarding age, sex, number of years of education, self-rated health status, medication use, and physical activity levels. Participants then filled out the State-Trait Anxiety Inventory form Y (STAI-Y) (Speilberger, 1983). Each experimental condition was preceeded by a period of practice. To avoid order effects or practice effects from systematically biasing the results, the 7 experimental conditions were counterbalanced across participants. To avoid strong negative reactions to task demands, the counterbalancing was arranged such that the easiest cognitive (i.e., identity matching) and motor task (i.e., unimanual tracking assessed at 0.25 rev/sec) conditions always preceeded more difficult conditions.

Results

Anxiety

There were significant age-differences in measures of state and trait-anxiety (see Table 1), with younger participants reporting higher levels of both state anxiety ($t(1, 161) = 3.06$, $p < .01$) and trait anxiety ($t(1, 161) = 2.39$, $p < .05$) than older participants. Surprisingly, both groups also reported lower levels of state than trait anxiety (younger adults $t(1, 73) = 5.02$, $p < .001$; older adults $t(1, 88) = 5.43$, $p < .001$), indicating that, in general, the testing situation did not provoke greater anxiety than participant's experience in general. Anxiety scores in both younger and older adult groups were distributed within the normal range of expected scores for their age-category (see Speilberger, 1983 for norms). As expected, state and trait anxiety were significantly inter-correlated 0.80 for younger adults and 0.69 for older adults. For the purposes of analysis of variance (ANOVA), it was decided to define high and low state and trait anxiety in younger and older adult groups in reference to their peers, i.e., by using the medians for respective cohorts to divide groups. This was done to avoid sampling bias and statistical bias in estimates. Median state and trait anxiety for young adults were 31 and 35 respectively, and for older adults 28 and 32 respectively. It should be noted that using medians for state and trait anxiety based on the full sample statistics did not significantly alter the results of the analysis presented below.

RT errors

Averaged across tests, less than 5% errors were made by the majority of participants, and no participants scored more than 10% errors. A three-way multiple analysis of variance (MANOVA) with age-group, trait anxiety group and state anxiety group as independent factors and error scores for the three word comparison conditions as dependent variables indicated no main effect for age-group, trait anxiety group or state anxiety group and no two or three way interactions ($p > .05$ for all). Error scores were not used in the calculations of RT medians.

Anxiety and performance in younger and older adults

Table 1 contains the means and standard deviations (SDs) for younger and older adult on measures of state and trait anxiety and in the seven experimental conditions.

Insert Table 1 around here

Basic statistical design was a mixed-factor analysis of variance with three between subject factors age-group, trait anxiety group and state anxiety group. Assuming that state anxiety and trait anxiety represent distinct factors (Spielberger, 1983; Eysenck, 1992), we were interested in examining main effects for both factors and any interactions between them.

Separate repeated measures ANOVAs were conducted for the word comparison task and the motor task. On the word comparison task there was a main effect for age-group ($F(1,160) = 162.77$; $p<.001$) and difficulty level ($F(1, 160) = 459.1$; $p < .001$) with older adults performing significantly slower than younger adults and both groups performing slower as task difficulty increased. There was an interaction between age-group and difficulty-level ($F(2,159) = 37.85$; $p < .001$) with older adults displaying significantly poorer performance as task difficulty increased. These results are clearly illustrated in figure 1 below.

Insert figure 1 around here

There were no main effects for either state ($F(1,160) = .87$; $p > .05$) or trait ($F(1,160)=.00$; $p > .05$) anxiety. Trait anxiety ($F(2,159) = 4.44$; $p < .01$), but not state anxiety ($F(2,159) = .91$; $p > .05$) interacted with task difficulty level with participants with high trait anxiety performing worse than low trait anxiety participants on the divided attention version of the semantic comparison task

In order to examine the interaction between age, anxiety and divided attention more closely a repeated measures ANOVA was run using the selective and divided attention versions of the semantic comparison task. A 3-way interaction of age-group x trait-anxiety x divided attention interaction ($F(1,164)=8.43$; $p<.01$) was observed. This interaction can be interpreted by reference to figure 2 where it can be observed that, unlike younger adults, older adults high on trait anxiety actually performed better than older adults low on trait anxiety for the semantic comparison, while both younger and older high-trait-anxious adults performed worse on the divided attention version of the semantic comparison. Post-hoc analysis of semantic decisions in the selective attention condition revealed no differences for younger adults ($F(1,164)= 1.47$; $p>.05$) and borderline significance for older adults ($F(1,164)= 3.83$; $p=.052$) high and low on anxiety (younger adult means = .97 and 1.06 secs, older adults means = 1.73 and 1.59 secs for low and high anxiety groups respectively). Post-hoc analysis in the divided attention condition revealed no significant differences for trait anxiety in either the younger ($F(1,164)= 1.48$; $p>.05$) or older adult ($F(1,164)= 1.03$; $p>.05$) groups (younger adult means = 1.12 and 1.24 seconds, older adults means = 2.03 and 2.12 seconds for low and high anxiety groups respectively).

Computing divided attention costs as a proportion of baseline task performance using the Salthouse and Somberg (1982) formula dual RT- single RT / single RT, the interaction between trait anxiety and age-group can be clearly seen (see figure 3).

Insert figure 2 around here

Insert figure 3 around here

The corresponding 3-way interaction between age-group, state anxiety, and task difficulty was not significant ($F(2,159)=.57$; $p > .05$). These results are consistent with the hypothesis that older adults who operate at sub-optimal levels of arousal (Jennings, 1989; Hasher & May, 1999) may benefit from the heightened arousal levels associated with anxiety for simple, more automatic tasks, but not for more complex, controlled tasks. All other higher-level interactions in this analysis were non-significant ($p > .05$).

On the motor tracking task there was a main effect for age-group ($F(1,160) = 162.77$; $p<.001$) with older adults performing significantly worse than younger adults. Entering all four pursuit tracking measures as a single repeated measures factor revealed an age-group x difficulty level interaction ($F(2,159) = 37.85$; $p < .001$), with older adults displaying significantly poorer performance as task difficulty increased. But given that the pursuit-rotor task manipulated task difficulty in two ways, i.e., by using fast and slow tracking speeds and by having participants track the target with and without a divided attention load we re-examined the age-group x task difficulty interaction using two repeated measures factors: pursuit-rotor speed (fast and slow) and pursuit-rotor attention load (selective or divided). As can be seen from figure 4 older adults demonstrated a larger decrement in performance relative to younger adults associated with the requirement to divide attention. The drop off in performance associated with the faster rotation of the target was similar for both younger and older adults.

Insert figure 4 around here

The trend observed in figure 4 was confirmed by the fact that there was a two-way interaction between age-group and pursuit-rotor attention load ($F(1, 160) = 20.0$, $p < .001$), but not between age-group and pursuit-rotor speed ($F(1, 160) = 1.8$; $p > .05$). There was also a tracking speed x attention load interaction ($F(1, 160) = 175.8$; $p < .001$) indicating that the impact of divided attention load was larger for slow than for fast tracking speeds, while the three way interaction between age-group, tracking speed and attention load only approached significance ($F(1, 160) = 3.0$; $p = .08$). These effects are best illustrated by reference to figure 5 where it can be seen that the impact of divided attention load was largest in the slow tracking condition, with older adults showing a steeper decrement in performance at slower tracking speeds.

Insert figure 5 around here

No main effects were observed for either state ($F(1, 160) = 0.08$; $p > .05$) or trait anxiety ($F(1, 160) = 0.04$; $p > .05$). There was an interaction between trait anxiety and pursuit-rotor speed ($F(1, 160) = 5.0$; $p < .05$) whereby high trait anxiety participants performed better at slow tracking speed and low trait anxiety participants performed better at fast tracking speeds. The corresponding interaction between trait anxiety and divided attention load was not significant, nor was state anxiety found to interact with either pursuit-rotor speed or divided attention load ($p > .05$ for all). An examination of figure 6 indicates that the two-way interaction between trait anxiety and pursuit-rotor speed can be accounted for in part by differences in the pattern of interaction for younger and older adults. Older adults high on trait anxiety performed better than those with low trait anxiety at slow tracking speeds and did not differ at fast tracking speeds. Younger adults showed the reverse pattern with high anxiety participants showing no difference from low anxiety participants at slow tracking speeds, but poorer performance at fast tracking speeds. The three way interaction between age-group, trait anxiety and tracking speed was not significant ($F(1,160) = .14$; $p > .05$). Post-hoc comparisons indicated the interaction between trait anxiety and tracking speed was significant for the younger ($F(1,74) = 4.32$; $p < .05$), but not the older adult group ($F(1,86) = 1.57$; $p > .05$).

This pattern of result is consistent with the results from the word comparison test, where older adults with high anxiety actually showed a trend toward performance facilitation when task difficulty was low but greater interference when task difficulty increased.

Insert figure 6 around here

The critical three-way interaction between age-group, trait anxiety, and divided attention load, significant in the word comparison task was not significant in the motor task [$F(1,160) = .14$; $p > .05$; Means for younger adults high and low on trait anxiety = 1189 and 1189 (single), 592 and 693(dual) respectively. Means for older adults high and low on trait anxiety = 1011 and 963 (single), 453 and 450 (dual) respectively]. No other higher-level interactions were observed.

Using the Salthouse and Somberg (1982) method proportion scores were obtained for the divided attention costs associated with both slow and fast tracking speeds as follows; (1) slow unimanual tracking - slow bimanual tracking)/slow unimanual tracking, and (2) fast unimanual tracking - fast bimanual tracking)/fast unimanual tracking. Therefore, for each proportion score computed, larger positive values indicated greater divided attention decrements. A re-analysis of the repeated measures ANOVA using divided attention proportion scores for slow and fast tracking revealed no significant interactions between age and trait anxiety ($F(1,160)=.06$; $p<.05$) or between age and state anxiety $F(1,160)=.03$; $p<.05$).

Finally, Pearson's correlations were computed between state and trait anxiety and the three proportion scores for the younger and older adults separately. The results of this analysis are summarised in Table 2 below. Results indicated that older adults with higher scores on state and trait anxiety displayed larger divided attention decrements when compared with older adults with low state and trait anxiety. Neither state nor trait anxiety were correlated with proportion scores of younger adults. Also, for both younger and older adults, correlations between state and trait anxiety and divided attention costs on the motor tracking task were non-significant.

Insert Table 2 around here

Discussion and conclusions

In the current study, we examined the relationship between state and trait anxiety and performance on word-pair comparison and pursuit tracking tasks in a sample of younger and older adults. Older adults showed significant decrements in performance on both tasks as task complexity increased. This finding is consistent with a large body of research demonstrating that older adults are selectively impaired when task complexity is increased across a range of tasks (Cerella, 1991; Myerson and Hale, 1993). Anxiety interacted with age, such that, to divide attention during semantic decisions was associated with significant slowing in decision speed, but not decision accuracy in older adults who reported high trait anxiety. In contrast, divided attention in a manual pursuit motor task was not negatively affected by high anxiety in either younger or older adults.

The results of the current study are consistent with reports by Cohen (1980) and Deptula et al. (1993) that there are age-related changes in relationship between anxiety and cognitive performance, but this study also provides the first demonstration of age-related changes in the relationship between anxiety and performance as task complexity increases. Results indicated that even after baseline performance levels were controlled for, word-pair decision speed under divided attention conditions was significantly slowed in older adults with high state and trait anxiety. This can be explained in part by the interesting trend observed whereby older adults high on trait anxiety demonstrated a trend towards facilitation of performance at lower levels of task difficulty, but greater interference when required to divide attention. The slowing of performance as task complexity increases in high anxiety older adults can be interpreted in the context of Eysenck's (1992) processing efficiency. Eysenck predicted that impaired processing efficiency produced by anxiety which can be compensated for by increased effort, can be detected by lengthened processing time on more difficult tasks. Support for this contention comes from studies which reported that high-anxiety participants spend more time studying for exams (Culler et al, 1980; Benjamin et al., 1981), more time reading text to achieve a comprehension level similar to low-anxiety participants (Calvo et al., reported in Eysenck, 1992). These results are also consistent with the hypothesis that older adults may operate at sub-optimal levels of arousal (Jennings, 1989) or be more negatively affected when tested at non-optimal times associated with changes in circadian arousal levels (see Hasher & May, 1999) and therefore may show moderate benefits from the heightened arousal levels associated with anxiety for simple, more automatic tasks. This suggests that the dual nature of anxiety, which is characterized by alterations in both arousal and cognition (Eysenck, 1982, 1992) may have a more complex relationship to age-related changes in performance than was previously predicted (Cohen, 1980, Deptula, 1993). Further research efforts are necessary to separate out the impact of anxiety-related fluctuations in arousal and cognitive interference in older adults, and to examine the testing conditions and task dimensions that either facilitates or disrupts performance in older adults who differ in levels of anxiety.

Contrary to the predictions of Eysenck (1992), higher levels of anxiety were not associated with significant slowing of semantic decisions in younger adults. This can be explained in part by the fact that younger adults with high trait anxiety made slower semantic decisions with and without a divided attention load. This lack of additional slowing associated divided attention load is consistent with the proposal of Deptula (1993) that younger adults with high anxiety are better able to compensated for any anxiety-related impairments by allocating addition processing resources in response to task demands.

In contrast to cognitive task performance, the current study found that a divided attention manipulation in a pursuit-rotor tracking task did not produce any anxiety-related decrements in performance. One interpretation of this result is that in the current sample, pursuit-rotor tracking, even when tested using fast pursuit speeds and attention divided to bimanual operations, did not provide sufficient task complexity to induce decrements in performance associated with increased distractibility that occurs when anxiety increases (see, Eysenck, 1982, and Mueller, 1992 for reviews). Research suggests that on simple tasks, increased anxiety has either no effect or yields some benefit (e.g., reduced distractibility; see Mueller, 1992 for a review). The task difficulty interpretation is weakened considerably by two key findings of the current study. Firstly, both younger and older adults showed large and significant decrements in pursuit tracking performance at faster tracking speeds and under conditions of divided attention. Furthermore, younger adults with high trait anxiety showed significantly poorer tracking ability at faster tracking speed when compared to younger adults with low trait anxiety. Once again, there was a trend for older adults with high anxiety to perform better than older adult with low trait anxiety when the task was less difficult (i.e., at slower tracking speeds).

An alternative explanation for the differential effects of anxiety on the cognitive and motor tasks used in the current study is available by reference to the model proposed by Humphreys and Revelle (1984). Humphreys and Revelle (1984) predicted that the effects of anxiety on performance vary depending on the task requirements. They made a distinction between sustained information tasks (SIT) and short-term memory tasks (STM). In SIT tasks, the participant is required to process a stimulus, associate an arbitrary response to the stimulus, and execute the response. No appreciable retention is required in SIT tasks. According to the theory STM tasks require participants to either maintain information in an available state or retrieve information that has not been attended for a short time.

Humphreys and Revelle (1984) reviewed research that was consistent with the prediction that those tasks with a substantial short-term memory component are relatively much more adversely affected by anxiety than those with a minimal involvement of short-term memory. In the current study the test of pursuit-rotor tracking, even under divided attention demands, is largely a sustained information task (SIT) with little or no involvement of short-term memory (STM). In contrast, semantic comparisons with concurrent letter search for word pairs involved the STM requirements to maintain and select semantic categories, letter targets, and a representation of response sequence. While the distinction between SIT and STM task requirements offers a reasonable explanation for the interaction between anxiety and divided attention during the cognitive and motor tasks used in the current study, it fails to explain why younger adults with high trait anxiety were significantly impaired when pursuit-rotor tracking speed was increased, or why older adults with high trait anxiety showed trends towards performance enhancement at lower levels of task complexity.

A limitation of the current design was that the manipulation of single/dual task demands in the cognitive, and motor tasks were not identical. The dual task condition in the motor task involved simultaneous performance on both tasks, while in the word comparison task participants responded sequentially, first to the word task and then to the letter task. This leaves open the possibility that different mechanisms account for the interaction between age, anxiety and divided-attention in both cognitive and motor performance domains.

There are a number of mechanisms whereby the secondary task requirements in the word comparison task may have disrupted performance on the primary task. These include; Interference between deep (semantic) and shallow (lexical) aspects of the task, inhibition of congruent response sequences (yes-yes/no-no) during incongruent (i.e., yes-no/no-yes) presentations, or, slowing due to limitations in processing speed associated with task difficulty rather than divided attention per se. On the other hand, it can be argued that divided attention costs are dependent on global task context (McDowd & Craik, 1988) and this makes a direct comparison between motor and cognitive task performance difficult. Previous research has demonstrated that the interactions between aging, divided attention and specific task parameters are complex. For example, McDowd and Craik (1988) varied the difficulty (i.e., depth of processing) and complexity (i.e., number of response alternatives) of tasks in a divided attention paradigm. They found that difficulty and not complexity increased age decrements described under dual task conditions and that decrements were not consistently amplified by increased task difficulty or complexity. On the basis of these findings and others (see e.g., Crossley & Hiscock, 1992) it has been argued that general slowing or diminution of a specific resource cannot account for age-related decrements in divided attention. Instead McDowd and Craik (1988), and Crossley and Hiscock (1992) suggest a reduction in a more general-purpose processing resource with increasing age. There is still considerable debate as to how generalized or specific these age-related changes are.

Future studies should examine the interaction between age, anxiety and performance in the cognitive and motor domains using tasks designed to vary both complexity (i.e., manipulating the number of response alternatives) and divided attention load (i.e., using both simultaneous and successive responding). It is possible that successive responding in multiple task situations represents a special class of divided attention load. Unlike simultaneous task performance, which relies heavily upon task-coordination skills (see Kramer, Larish & Strayer, 1995; Kramer, Hahn, & Gopher, 1999), the emphasis in successive responding is on executive control over response sequences where rapid attention switching is central to successful performance. Aging is known to slow the speed of attention switching (Mayr & Liebscher, 2001, Meiran, Gotler & Perlman, 2001). Anxiety could interfere with performance during switching by inserting task-irrelevant thoughts at the point of a task switch. This could compound divided-attention costs by adding a switch cost.

Eysenck (1992) proposed that, although trait and state anxiety correlate as highly as 0.70 or more with each other, internal processing and performance are determined by state anxiety rather than trait anxiety. Although state and trait anxiety were highly intercorrelated in the current study, it was found that trait anxiety was the better predictor of divided attention decrements in older adults. Variance estimates and correlations may have influenced by lower levels of reported state anxiety in both younger and older adults that were closer to basement in older adults. One explanation for the reduced self-reporting of state-anxiety is that participants in the current study were more reluctant to report pre-test anxiety, and more likely to report generalized anxiety. Given the central importance of state anxiety in models of information processing efficiency (see, Eysenck, 1992), future studies that aim to examine how anxiety mediates performance in younger and older adults should play close attention to methodological issues associated with obtaining reliable and valid estimates of state anxiety. However, the current study did demonstrate that the divided attention decrements for semantic decision RTs made by older adults were robustly correlated with both state and trait anxiety subscales when baseline performance was controlled. Furthermore, the results of the current study are interesting because the link between trait anxiety and divided attention decrements in older adults suggests that anxiety may be a stable individual difference factor with implications for the performance of older adults in other situations where cognitive complexity is increased.

The findings reported here highlight the importance for understanding the impact of anxiety on the availability and allocation of information processing resources in older adults. There are numerous theoretical, methodological and applied reasons for pursuing research on the link between anxiety and performance in older adults. Firstly, the possibility that there is a differential impact of anxiety in older adults as task complexity increases is an important finding. One implication is that research may exaggerate estimates of age-related cognitive decline if younger and older adults are not adequately matched for anxiety-level or if anxiety-level is not statistically controlled in estimates of age-differences.

Secondly, it is unclear from research to date if the cognitive changes typically observed as people age are related in any systematic way to the chronic or acute effects of anxiety. One question that should be addressed by future research is if anxiety magnifies memory deficits that are already sensitive to the effects of aging or if anxiety acts selectively on different memory subsystems (see Light, 1991 for a review). For example, recent research suggests that anxiety and stress may have detrimental effects on the hippocampus (Gurvits et al., 1996), a brain area critical for some forms of memory. Given that aging is normally associated with neural degeneration in the hippocampus, it is of critical importance to understand if anxiety acts to speed up this age-related degeneration so that interventions designed to alleviate anxiety in older adults can be implemented when necessary (see e.g., Bremner & Narayan, 1998).

Thirdly, if as suggested by Eysenck (1982, 1992) anxiety results in cognitive interference, it would be invaluable to investigate if the age-related decrements observed for executive control (Stuss & Benson, 1987) or attentional inhibition (Zacks & Hasher, 1993) and working memory (Salthouse, 1992) are further disrupted under conditions of high anxiety and if this disruption has any effect on the functional and cognitive abilities of older adults.

Finally, the results of this study suggests that cognitive models accounting for the age-related decline in performance when task complexity is increased (Cerella, 1990) which so often cite reduced resource availability and reductions in processing speed as causal mechanisms (Myerson and Hale, 1993; Salthouse, 1995) may benefit from further consideration of how personality variables moderate the allocation and availability of resources in older adults. The critical question here is whether of not chronic levels of trait anxiety can have a detrimental effect on the CNS which further reduces the depleting reserve of resources available for cognitive processing, or if anxiety merely affects how resources are allocated during cognitive tasks.

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Table 1: Means and standard deviations (SDs) for younger and older adult on measures of state and trait anxiety and in seven experimental conditions.

	Younger Adults		Older Adults	
	Mean	SD	Mean	SD
State Anxiety	32.65	7.32	28.90	7.78
Trait Anxiety	35.69	8.38	32.70	8.45
Word Comparison Task				
Identity matching RT	0.64	0.10	0.94	0.18
Semantic matching RT	1.02	0.27	1.66	0.40
Divided attention RT	1.19	0.32	2.08	0.48
Motor Tracking Task				
Unimanual tracking at 0.25 rev/sec	1387.76	116.02	1261.85	187.60
Unimanual tracking at 0.5 rev/sec	719.46	260.90	554.87	243.85
Bimanual tracking at 0.25 rev/sec	1019.03	204.66	711.62	314.20
Bimanual tracking at 0.5 rev/sec	594.87	201.39	350.41	196.15

Table 2: <u>The correlation between trait anxiety and RT performance in dual-task relative to single-task conditions for younger and older adults.</u>

Proportion score	Younger adults		Older adults	
	State Anxiety	Trait anxiety	State Anxiety	Trait anxiety
Word Comparisons	0.09	.08	0.25*	0.39**
Slow Tracking	0.08	.17	-0.02	-0.12
Fast Tracking	-0.06	-.05	0.18	0.14

* p < .05, ** p < .01

Figure headings

Figure 1. Word comparison RTs for younger and older adults in three experimental conditions.

Figure 2. Selective and divided attention semantic comparison RT means for younger and older adults with low and high trait anxiety.

Figure 3. Trait anxiety x age-group interaction[a] for divided attention RT proportion score[b] .

[a] $F(1, 158) = 9.83$, $p < .01$

[b] Divided attention RT – single task RT/single task RT

Figure 4. Average decline in performance associated with divided attention and increased pursuit-rotor speed in younger and older adults.

Figure 5. Divided attention decrements for both slow and fast pursuit speeds in younger and older adults.

Figure 6. The impact of trait anxiety on the tracking performance for younger and older adults at slow and fast pursuit speeds