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EFFECTS OF AGING AND THE DEVELOPMENT OF AUTOMATIC AND CONTROLLED SKILLS IN DRIVING

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SUMMARY

The magnitude of age effects in single- and dual-tasks may be affected by the degree to which the tasks require automatic or controlled processing (Hasher and Sacks, 1979) and whether skills of older subjects are familiar and developed before old age or novel and developed during the experiment (Fisk, McGee and Giambra, 1988). In addition, age-effects may be affected by emergent dual-task characteristics (Korteling, 1991, 1992), and by overall task complexity ("Complexity hypothesis" e.g., McDowd and Craik, 1988).
Effects of the first three task variables were addressed in an experiment, in which experienced subjects performed a vehicle steering task (automatic processing) and a car following task (controlled processing) in a driving simulator. The controlled task was performed under two conditions of Novelty. In one condition, the gas pedal functioned normally (skill development before old age), while in the other condition it functioned in an inverted way. This implies that the subjects only practised this latter task condition during the experiment (skill development after old age). In dual-task performance, difficulty of both subtasks was constant or variable. In the latter case, subtask difficulty alternated in counterphase.
The single-task results indicated that the older subjects performed poorer than their younger counterparts only in the car-following task, with an invertedly functioning gas pedal. Also in dual-task performance, an age-effect was found when this controlled task was performed with inverted gas pedal functioning. In that case, the age-effect was found in the automatic subtask. In conclusion: in automatic and in controlled processing tasks as well, age-effects appear when subjects can not utilize skills that were previously developed. Dual-task costs were basically manifested in the controlled task. Counterphase difficulty alternation did not affect task performance at all, which may be explained by the fact that this variation probably was so clearly imposed by the task, that adequate behavioral adaptations automatically were elicited. Post-hoc interpretations of the data indicated that these were not completely consistent with the complexity hypothesis.

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Effecten van leeftijd en de ontwikkeling van automatische en gecontoleerde vaardigheden bij autorijden

J.E. Korteling

SAMENVATTING

De grootte van leeftijd-effecten in enkel- en dubbeltaken wordt mogelijk beïnvloed door de mate waarin de taken automatisch of gecontroleerd worden uitgevoerd (Hasher and Sacks, 1979) en door de mate waarin een beroep gedaan wordt op recent ontwikkelde, dan wel reeds bestaande automatismen die vóór het ouder worden werden geleerd (Fisk, McGee and Giambra, 1988). Daarnaast kunnen leeftijd-effecten beïnvloed worden door emergente dubbeltaak eigenschappen (Korteling, 1991, 1992) en door taakcomplexiteit ("Complexiteitshypothese", b.v., McDowd and Craik, 1988).
De effecten van de drie laatstgenoemde variabelen werden onderzocht in een rijsimulatie-proef waarin rijvaardige proefpersonen een stuurtaak (automatisch) en een volgtaak (gecontroleerd) uitvoerden. De gecontroleerde taak werd op twee niveaus van bekendheid uitgevoerd. In één conditie functioneerde het gaspedaal normaal (geleerd voor de ouderdom), terwijl in de andere conditie het gaspedaal omgekeerd functioneerde. Dit laatste betekent dat deze taakconditie alleen tijdens het experiment werd beoefend (geleerd na de ouderdom). Tijdens de dubbeltaken was de taakmoeilijkheid constant of variabel. In het laatste geval alterneerde de moeilijkheid van de deeltaken in tegenfase.
De enkeltaak-resultaten lieten zien dat de ouderen minder goed dan de jongeren presteerden in de volgtaak met omgekeerd gaspedaal. Ook bij de dubbeltaak werd een leeftijdseffect gevonden wanneer deze gecontroleerde taak met een omgekeerd functionerend gaspedaal werd uitgevoerd. Het leeftijdseffect kwam hier in de automatische deeltaak tot uiting. Kortom, in automatische taken, maar ook in gecontroleerde taken treden leeftijdseffecten op wanneer geen beroep kan worden gedaan op vaardigheden die voor het ouder worden werden geleerd. Dubbeltaak-kosten kwamen vooral naar voren in de gecontroleerde taak. Het in tegenfase alterneren van taakmoeilijkheid had geen invloed op de taakprestaties, hetgeen verklaard kan worden door het feit dat de moeilijkheids-variatie zo duidelijk door de taak werd opgelegd dat adequate gedragsaanpassingen hierdoor automatisch werden uitgelokt. Achteraf bezien bleken de resultaten niet volledig in overeenstemming met de complexiteitshypothese.

1 INTRODUCTION

In a wide variety of laboratory experiments, older adults are found to have difficulties in dual-task performance (Broadbent and Gregory, 1965; Caird, 1966; Clark and Knowles, 1973; Craik, 1965; Inglis and Ankus, 1965; Inglis and Caird, 1963; McDowd, 1986; Ponds, Brouwer, and Van Wolffelaar, 1988; Salthouse, Rogan and Prill, 1984; Talland, 1962). Since many everyday and occupational activities also involve the performance of simultaneous actions, aging-related decrements in multiple-task capabilities will have critical implications for a rapidly growing segment of the population. However, in order to take measures aimed at the design of a better adapted and supportive environment, more specific knowledge is needed concerning the task characteristics that may determine the magnitude this age effect.

Recently, it has been suggested that the degree and nature of similarity between subtasks (Wickens, 1989, 1992) may be a factor determining the magnitude of age differences in dual-task performance (Korteling, 1991, 1993). Similarity refers to basic task characteristics, such as stimulus-response mapping, mental set, processing routines, spatial or temporal similarities, or similarity of colour and form. The effects of similarity on time-sharing may act as a two-edged sword, which can sometimes enhance the efficiency of dual-task performance and sometimes degrade it. When similarity refers to related tasks with compatible timing routines and stimulus-response mapping, coordination or integration of subtasks often may be facilitated and thus performance may improve (e.g. Duncan, 1979, Korteling, 1991; Klapp, 1979, Peters, 1977). Klapp (1979), for example, pointed at superior time-sharing in simultaneous rhythmic activities when temporal patterns were compatible and Peters (1977) showed that the magnitude of interference effects in two motor tasks decreased with the degree to which the concurrent rhythms could be made compatible. In fact, it can be argued that many everyday dual-tasks, like oral reading, piano playing, or vehicle control, may entail such a high degree of internal compatibility and relatedness that they are easily experienced as single-tasks. With reference to age-related differences, Korteling (1991) found that in a simple dual compensatory tracking task, young subjects did not outperform the older subjects, except when the pointers of two tracking tasks made synchronous movements. Apparently, synchronization of constituent tasks enabled only the young to integrate, or combine, these separated activities. This has been termed *skill integration* or *performance integration*. It was concluded that older subjects may be less able to perform coherent dual-tasks efficiently, which may be caused by limitations in the integrated uptake and processing of information from multiple sources, and/or limitations in combining related actions.
Similarity may also degrade time-sharing efficiency. When similarity only involves *concrete and superficial elements* of the dual-task in terms of space, colour, or form, while stimulus-response mapping between subtasks is incompatible or unrelated (*representational similarity*), confusion or cross-talk may result. In that case, it will be more difficult to keep the tasks separate. Subjects may then unin-

tentionally combine the subtasks, such that the constituent tasks will become more susceptible for mutual disruption (e.g., Navon and Miller, 1987). With respect to focused attention tasks, Stroop interference is a good example of this kind of phenomenon. In dual tracking tasks, Fracker and Wickens (1989) showed that cross talk, that is, the degree to which error of one subtask was affected by unwanted control responses of the hand controlling the other task, may increase when the displays and controls of the two axes were made more similar by integrating them.
With respect to aging, Korteling (1993) found that in dual axis tracking, age-effects in terms of tracking error and cross-talk, were increased by similarity-based confusions, i.e., incompatibility between stimulus and response integration and representational similarity.
In conclusion, task characteristics *emerging from the relationship between subtasks* may have considerable impact on the magnitude of age differences in dual-task performance. This decreasing ability of the older to handle the relationships between tasks, may relate to deteriorations with regard to attention switching, prioritizing the appropriateness of multiple sources of information, and combining related actions.

Another variable which may be an important determinant of age differences in dual-task performance, is overall task complexity. In simple perceptual-motor tasks, age-related differences often are found to be small or absent. Otherwise, increasing the difficulty of tasks, has been found to enlarge the magnitude of the age effect (e.g., Birren, Woods and Williams, 1980; Cerella, 1985; Cerella, Poon and Williams, 1980; Hale, Meyerson and Wagstaff, 1987; Meyerson, Hale, Wagstaff, Poon, Smith, 1990; Welford, 1958, 1965, 1977). Salthouse (1982) suggested that a dual-task is nothing more than a complex version of a single-task, which necessitates the involvement of more mental operations. This means that observed age effects of complex single-tasks and dual-tasks are the same in nature. The substantial age-related performance differences in dual-tasks may therefore be caused by the mere complexity of these tasks, and nothing else (e.g., Salthouse, 1982; Salthouse et al, 1984). This so called "complexity hypothesis" has been substantiated by McDowd and Craik (1988), who found that age-related differences in dual-task performance largely were determined by the complexity of the overall task situation. In their study, RT performance of the old subjects could be predicted on the basis of younger subjects' performance, without regard to the nature of the task. "Complexity", however, provides little more than a label. We should address the underlying processes that lead to age-effects in multiple-task situations (e.g. Fisk and Rogers, 1991; Korteling, 1991, 1992).

Age-related differences may also be affected by the amount of attentional capacity required by the task. In this respect, two different modes of information processing are discerned (e.g., Fisk, Ackerman, and Schneider, 1987; Hasher and Zacks, 1979; Logan, 1978; Posner and Snyder, 1975; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977, 1984), which mostly are referred to as *automatic* and *controlled* processing (Schneider and Shiffrin, 1977). Automatic processing is fast, parallel, effortless, and not under direct subject control. It usually is regarded as an important contributor to well-developed skilled behaviour, but it only develops when tasks are characterized by an invariant relationship between stimuli and responses (consistent mapping). Once learned, automatic processes are difficult to suppress, modify, or ignore. Finally, it is thought to be relatively invulnerable to individual differences. In contrast, controlled processing is generally regarded as slow, serial, effortful, capacity limited, subject regulated and needed in situations where responses required to stimuli are inconsistent (varied mapping). Controlled responses are easily modified, suppressed, or ignored. In tasks requiring controlled processes a wide range of individual differences may be seen.

Complex tasks may consist of a combination of automatic and controlled components. Hasher and Sacks (1979) postulated that in controlled tasks, requiring attentional capacity, age-effects are large, whereas in tasks that permit automatic processing, differences between young and older subjects tend to disappear. In line with this, Madden and Nebes (1980) found, in a hybrid memory-search/visual-search paradigm, that automatic processing over practice developed at equivalent rates for older and young subjects, although search performance of the older subjects was substantially slower. However, Fisk, McGee and Giambra (1988) demonstrated that *after* old age, the degree with which older subjects can acquire new automatic processes (in visual search) declines. They suggested that only previously developed automatic processing, may remain effective on old age. In addition, Fisk and Rogers (1991) mention data in the areas of Stroop interference, lexical access, and implicit memory that are compatible with age-independency in long-practised, previously developed processed as opposed to the development of new automatic processes in later adult life. Finally, it has been shown that subjects can develop automatic processes based on global consistencies in the relationships among stimuli, which overrule more local inconsistencies on the level of individual stimuli (Fisk, Oranski and Skedsvold, 1988). This may be meaningful for complex everyday (dual-)tasks which also entail these kinds of higher-order relationships.

Therefore an important question is whether problems of older people are also manifested in (multiple-) tasks, which were already practised before old age for a long time in daily life. These kinds of (everyday) tasks usually are characterized by an invariant relationship between stimuli and responses, and thus will be performed in an automatic mode. For example, in steering a car, the relationship between lane position/heading and required steering actions on normal roads is consistent. This task is also frequently performed by many people during a large part of their life. Moreover, in steering, the frequency of stimulus-response sequences is high; the "steering action rate" during normal driving is about 30 times per minute (e.g., Verwey, 1991). Therefore, for experienced drivers this low-level component of driving may be supposed to require minimal attention.

With regard to dual-tasks, it may be supposed that a controlled task combined with an automatic task will produce smaller interference effects, than the simultaneous performance of two controlled tasks. Indeed, Schneider and Fisk (1982) showed that dual-tasks sometimes even can be performed without

noticeable deficit when one of the tasks is automatic. In their study, the controlled task was most sensitive to deterioration. This is in accordance with the results of some more practical studies, indicating that basic and automatized driving or bicycling skills are relatively insensitive to more controlled skills, such as telephoning and perception and decision-making tasks, as long as there is no motor interference. (e.g., Brown, Tickner, and Simmonds, 1969; Brookhuis, de Vries and de Waard, 1989; Wierda and Brookhuis, 1991).
On the basis of this brief review, we may expect that effects of age in single- *and* in dual-task performance will depend of the degree to which a task involves automatic *vs* controlled processing and whether or not it involves previously well-trained processes (a factor which may be called "Novelty"). For example, we do not expect substantial age differences in well-practised tasks requiring automatic processing, when the tasks are extensively practised before reaching old age (e.g., Fisk and Rogers, 1991). However, a question that still remains is whether or not we may expect age differences in a well-developed, previously learned, task that still has to be performed in a controlled mode.

In order to be able to evaluate the behavioral age-effects in practical multiple-tasks such as car driving, consisting of a combination of automated and controlled processes and novel and previously learned related subtasks, this topic requires more definite answers. Therefore, the present experiment addressed two topics relevant for task performance in these circumstances.
1) The effects of an emergent *dual-task variable, i.e., whether or not the* difficulty levels of subtasks were alternating in counter-phase, which involves the ability of attention switching and prioritizing multiple-task components.
2) Furthermore, the experiment aimed at effects of processing mode and whether or not well-trained skills were previously developed with respect to single- and dual-task performance.
In order to eliminate problems concerning the interpretation of experiments evaluating effects of task familiarity (Salthouse, 1990), a well-documented task was used in which familiar and unfamiliar conditions were matched on complexity. When relevant, the data were checked on compatibility with the complexity hypothesis.

2 METHOD

2.1 Subjects

Two age groups of 12 subjects participated in the experiment, each consisting of 10 males and 2 females. The mean age of the old subjects was 70 (range 65-74, sd 2.9); the mean age of the young was 27 (range 21-34, sd 5.3). By frequency distribution control, the subjects were matched on level of education. Subjects were controlled for health and had normal or corrected to normal visual acuity. Age-corrected scores of the subject groups on Digit-Symbol Substitution of the

Dutch version of the Wechsler Adult Intelligence Scale (WAIS), were not significantly different. Subjects were paid for their participation. All subjects were experienced drivers (> 10000 km driven over the last 5 years). However, total driving experience for the old subjects was significantly higher (mean 75000 km, sd 55000 km) than for the young subjects (mean 55000 km, sd 36000 km).

2.2 Apparatus

The experiment was conducted in the driving simulator of the TNO Institute for Perception. Fig. 1 gives the basic configuration of this fixed-base driving simulator.

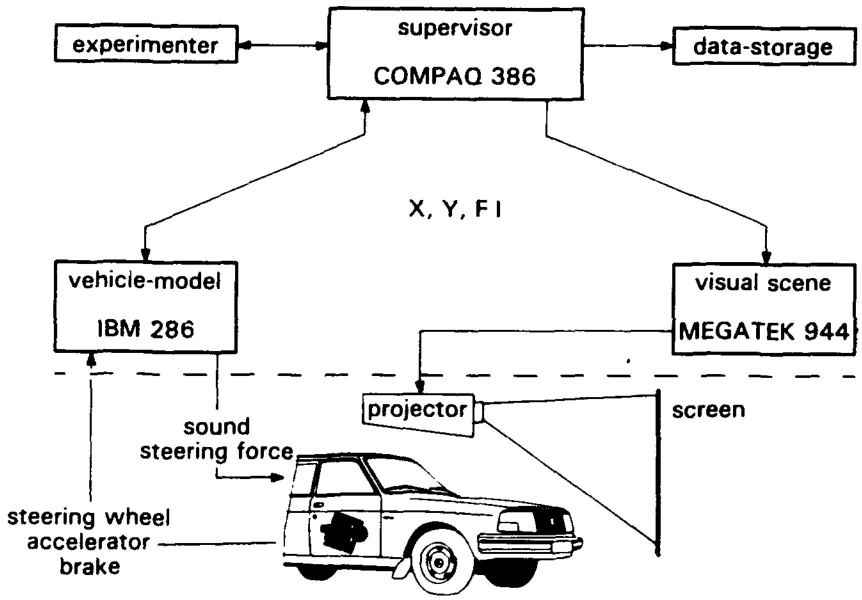

Fig. 1 Basic configuration of the TNO driving simulator.

The control system has a modular design with three sub-systems:

- The <u>supervisor</u> computer (COMPAQ 386) with tasks such as communication with both the experimenter and the other sub-systems, the control and monitoring of the experiment, data-storage, etc.,
- the <u>vehicle-model</u> computer (IBM 286) for calculating the momentaneous position (X-, Y-, and FI-coordinates) of the simulated vehicle; this vehicle has the dynamic characteristics of a Volvo 240, and
- the <u>visual scene</u> computer (Megatek 944 CGI-system) that generates real-time images with a update rate of 30 Hz.

The subject is seated in a fixed-base mock-up of a Volvo 240 containing all normal controls (steering-wheel, accelerator, gear-shift, brake, etc.). Based on the status of these controls, the vehicle-model computes the consequences in terms of speed- and heading changes, in a similar way as a real vehicle would react to driver's actions. Feedback of steering forces is given to the driver by means of an electrical torque engine, and of sound by a electronic sound-generator (noise of engine, wind, and tires). The momentaneous position (X,Y) and heading-angle (FI) are transmitted via the supervisor to the visual-scene computer. The CGI-system computes the corresponding visual scene as seen from the driver with a resolution of 1024 x 1024 pixels in full colour (24 bit RGB). This image is projected on a screen in front of the mock-up by means of a high-resolution BARCOGRAPHICS 800 projector with a display rate of 60 Hz. The horizontal and vertical visual angles of the image on the screen were 40°. This resulted in a resolution of 26 pix/degr.

2.3 Experimental tasks

In the TNO driving simulator, subjects had to perform a steering task, which was completely automated (when the stimulus-response relation was varied, subjects could not perform this task) and a more demanding, i.e., controlled car-following task. In the dual-task conditions, the steering task was combined with the car-following task. Fig. 2 shows the basic characteristics of the image as seen by the driver sitting in the TNO driving simulator.

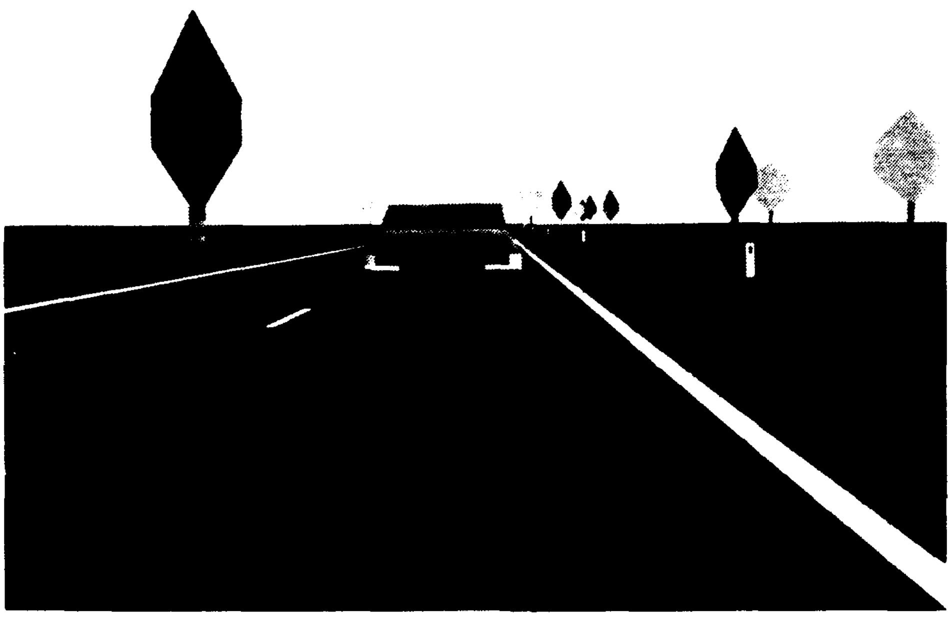

Fig. 2 The outside view seen from the driver's position.

Steering task

In the driving simulator subjects drove 15 m behind a lead car on the right lane of a straight freeway (lane width: 360 cm). The transmission was always in the third gear and driving speeds of both cars were fixed at 80 km/h. The lead car drove exactly on the middle of the lane. Subjects were requested to keep their vehicle on the middle of their lane as well as possible, right behind the lead car. Based on a forcing function simulating windgusts (see section "disturbance inputs"), the course of the vehicle was varied such that subjects had to make compensatory steering movements in order to keep their vehicle on the middle of the lane. Performance in the steering (sub)task was measured by calculating the standard deviation of the vehicles lateral position on the road.

Car-following task

In this task, subjects followed a lead car that continuously changed driving speed. Both cars drove on the middle of the right lane. Subjects were requested to maintain a distance of 15 m between both cars. Because this aim is rather ambiguous, subjects were assisted by a dark bar, projected 15 m in front of their car on the road. When the near end of the bar was between the back wheels of the lead car, the inter-vehicle distance was exactly 15 m. Again, the speed of the lead car was varied by a forcing function. Subjects only could use the gas pedal in order to compensate for the resulting variations in inter-vehicle distance. The transmission was again in the third gear and the car-following task did not require gear changes. Mean speed of the lead car was always 80 km/h. Performance in the car-following (sub)task was rated by calculating the standard deviation of the inter-vehicle distance.

Disturbance inputs

In the steering and car-following task, respectively, course of the vehicle and driving speed were varied by the same random band-limited (frequency < 0.4 Hz) pink noise forcing function. The gains of this function were set such that, subjectively, both tasks were equally difficult. With respect to lateral position on the road, this resulted in a sd of 36 cm (range: 94 right - 120 left). With respect to driving speed of the lead car, this resulted in a sd of 5.5 km/h (range: 62-94). The forcing function consisted of 10000 points that were computed before the experiment. To allow continuous transgression when the end was reached, the beginning and the end of the forcing function were adjusted. For each experimental trial, the starting points within the forcing function were chosen randomly.

2.4 Independent variables

Both tasks were carried out under single- and under dual-task conditions. This resulted in two single tasks (as described above) and one dual-task (steering combined with car-following).
In order to evaluate effects of the degree to which a task is practised before or after old age (and to be sure that car-following could be regarded as a controlled task), the car-following task was performed under two conditions of Novelty. In the normal condition, the gas pedal functioned as usual: pushing resulted in acceleration and releasing resulted in deceleration. In the other condition, the output signal of the gas pedal was inverted, such that pushing this pedal resulted in slower driving, whereas releasing resulted in acceleration. Hence, in this latter condition, the stimulus-response relationship corresponded to that of a brake pedal. The relationship between pedal displacement and resulting deceleration, however, still corresponded to pedal displacement and resulting acceleration of the normal gas pedal. This inverted condition was considered less familiar to the subjects, while the complexity (not the difficulty) of the task was supposed to be identical to car-following with normal gas pedal functioning.
There was no condition with inverted steering wheel functioning. When, in pilot studies, the steering wheel output was inverted, many subjects could not perform the task. They often drove into the field and sometimes could even not find their way back to the road, which makes the task qualitatively different. Apparently, subjects could not suppress and modify priory learned reactions in this task. This was not the case for inversion of gas pedal functioning in the car-following task. The young subjects, for example, showed an equal task performance in both conditions of Novelty. Based on these data, the steering task was considered as an automated task, whereas the car-following task was regarded a controlled task.
In order to test the hypothesis that older subjects perform relatively poor in tasks containing emergent dual-task characteristics, all single- and dual-task configurations were performed in two conditions. In one condition, difficulty of the subtasks was held constant and in the other condition, difficulty alternated by changing the gain of the disturbance signal between two values, ten times each trial. In these latter task conditions, this Difficulty Alternation was such that it alternated between subtasks *in counter-phase*; that is, when one subtask became more easy, the other simultaneously became more difficult. It was assumed that old and young subjects would differ in the degree to which they are able to perform the subtask in combination and thus to switch attention and to distribute it in proportion to the changing difficulty levels of the subtasks (prioritizing).
The two fixed levels between which subtask difficulty alternated were based on a multiplication of the subtask-gains with 0.6 (easy) or with 1.4 (difficult). With respect to lateral position on the road, this resulted in a sd of 22 cm (range: 56 right - 72 left), and of 51 cm (range: 150 right -168 left) in the easy and difficult intervals, respectively. With respect to driving speed of the lead car, this resulted in a sd of 3.3 km/h (range: 69-89) or of 8.8 km/h (range 51-103) in the easy and difficult intervals, respectively. In pilot studies, it appeared that effects of

Difficulty Alternation were linear within the range (0.6-1.4) in which difficulty was varied. Hence, within this range, no saturation effects were expected.

The design is presented in Table I

Table I A representation of the experimental design. In the dual-task conditions, the steering task was combined with one of the two Novelty conditions of the car-following task.

		difficulty alternation		no difficulty alternation	
		single	dual	single	dual
steering task	automatic, devel. before old age				
car following task	controlled, devel. before old age				
	controlled, devel. after old age				

As can be seen in this table, automaticity and Novelty (before *vs* after old age) were not completely factorialy combined. This is caused by the fact that a practical task was required to investigate effects of automaticity developed before old age and that this factor usually will be confounded with the degree of automaticity. Furthermore, if the steering task was inverted like the car-following task, the steering task would be variably mapped such that it would become a controlled task.

2.5 **Data collection**

Error was sampled and stored for analysis with 30 Hz. Each trial, this was measured in 10 intervals in which the gain of the disturbance signal was constant. These ten periods were connected by 10 "transition periods". In the experimental conditions, a trial was preceded by a warming-up period. Only in the conditions with alternating task difficulty, the transition periods were actually used in order to vary the gain of the disturbance signal. In the warming-up period and in the transition periods, no data were collected. The 10 measurement intervals in the experimental trials took 18 s each.

2.6 **Procedure**

Subjects participated during a one-day session. Each day two subjects were tested such that one subject relaxed while the other performed one block of single- or dual-task trials. Subjects were seated in the simulator room. The experimenter was situated in an adjacent room from where he could communicate with the subjects via an intercom.

Practice blocks

The practice blocks started with a short introduction about the nature of the experiment. Subjects were instructed to devote always the same amount of total effort to performance regardless of the number of subtasks required. On dual-task trials, subjects were instructed to keep performance on both subtasks as equal as possible. After the general instructions, the subjects practised in two single-task blocks and two dual-task blocks. During practice, a dual-task block was always preceded by a single-task block. In order to control for sequencing effects, however, the order of conditions within blocks was counterbalanced between groups. In a single-task practice block, each single-task condition was performed once. Hence, a single-task practice block was comprised of six trials, that is steering in two conditions of Difficulty Alternation and car-following in four conditions, created by the factorial combination of Novelty with Difficulty Alternation.

Like single-task practice, for each dual-task condition one trial per block was done. This resulted in four trials per block, that is: two conditions of Novelty x two conditions of Difficulty Alternation.

Since transition periods lasted 3 s and "*measurement intervals*" lasted 9 s, a practice trial took 120 s (10 x 3 + 10 x 9). Trials were interrupted by a 20 s rest period.

Experimental blocks

The experimental blocks differed in three respects from the practice blocks: 1) also the sequence of single- and dual-tasks was counterbalanced, 2) each trial started with a warming-up period of 15 s 3) the measurement intervals lasted 18 s instead of 9 s. Therefore all trials lasted 225 s (15 + 10 x 3 + 10 x 18). For the rest, everything was equal, i.e., four experimental blocks (two dual-task blocks and two single-task blocks), six trials per single-task block and four trials per dual-task block. Again, all trials were interrupted by a 20 s rest period, except in the middle of a block, when a pause of one minute was given.

2.7 Data analysis

Data were analyzed with ANOVAS in which subjects were nested under the two age groups. In order to control for effects of age differences already present under single-task conditions, for each dual-task condition, only data associated with pure dual-task performance had to be taken into consideration (Somberg and Salthouse, 1982). Therefore, dual-task performance was expressed as the difference between the measured dual- and single-task standard deviations divided by the single-task standard deviations, i.e., under the comparable conditions (e.g., McDowd, 1986). In this manner, eventual age-related differences in dual-task performance could not be confounded by initial differences in steering and speed control abilities.

3 RESULTS

3.1 **Single-tasks**

Steering task

Single-task steering performance was analyzed in a 2 (Age) x 2 (Difficulty Alternation) ANOVA. The standard deviation of lateral position was 23 cm for the young subjects and 21 cm for their older counterparts. This difference was not significant. Older subjects use to perform poorer in laboratory tracking tasks that are not extensively practised before old age (e.g. Korteling, 1991). Therefore, this result corroborates the idea that in skilled automated tasks, which are extensively practised before old age, age-related performance differences tend to disappear (Fisk et al., 1988; Fisk and Rogers, 1991).
There was no main effect of Difficulty Alternation, nor was there an Age x Difficulty Alternation interaction. This shows that for both age groups, effects of this variable on task performance were linear within the range (0.6-1.4) with which difficulty was varied. In order to prevent saturation effects, in pilot experiments, the degree of difficulty alternation was set such that the relation between disturbance gain and steering performance would become linear.

Car-following task

Single-task car-following performance was analyzed in a 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) ANOVA. As can be seen in Fig. 3, with respect to this task, the older subjects performed poorer than the young subjects, $F(1,22) = 16.3$, $p < .001$. There was also a significant effect of Novelty, $F(1,22) = 27.6$, $p < .0005$, which interacted with age, $F(1,22) = 12.3$, $p < .005$). A separate analysis with respect to this interaction showed that the difference between old and young subjects was not significant in the normal condition. Hence, the age effect can be explained almost completely by the poor performance of the older subjects in the condition with inverted gas pedal functioning. This demonstrates an age-effect only when the task is novel. Because car-following is a controlled task, the notion of age-independence in familiar tasks not only involves automated processes (Fisk et al., 1988), but also controlled processes. The data are clearly not in accordance with the slowing-complexity hypothesis, because car-following with inverted gas pedal functioning and normal gas pedal functioning were of an equal complexity, which is signified by the unaffected performance levels of the young subjects under both Novelty conditions.

Again, there was no main effect of Difficulty Alternation, nor was there an Age x Difficulty Alternation interaction. Therefore, for both age groups, effects of this variable on task performance were linear within the range (0.6-1.4) in which difficulty was varied.

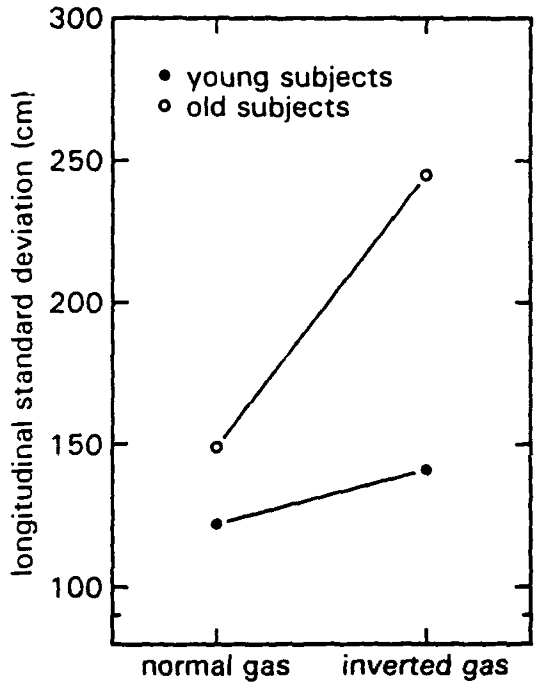

Fig. 3 Single-task car-following performance of both age groups, as affected by Gas Control Novelty.

3.2 Dual tasks

Steering performance

Since dual-task performance was expressed as the degree of performance variation relative to single-task performance under the same conditions, these *relative* performance data were termed *dual-task costs*. For steering performance, these dual-task costs were analyzed in a 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) ANOVA. In this analysis, Novelty referred to whether or not the steering task was *combined* with the normal car-following task, with which all subjects were familiar, *vs* the unusual car-following task, which was never practised before the experiment.

This analysis did not show a significant effect of Age ($p < 0.20$) or of Difficulty Alternation. However, there was a significant effect of Novelty, $F(1,22) = 7.8$, $p < 0.05$, which interacted with Age, $F(1,22) = 7.8$, $p < 0.05$. Figure 4 shows that the older subjects only were more hampered by the extra car-following task when this task was not practised before old age. Therefore, the data substantiate the hypothesis that also in a dual-task, task performance becomes poorer when at least one of the subtasks is not extensively trained before old age. The results of the young subjects show that both conditions of the factor Novelty were equally complex. Therefore the Age x Novelty interaction is not predicted by, and thus incompatible with, the slowing-complexity hypothesis.

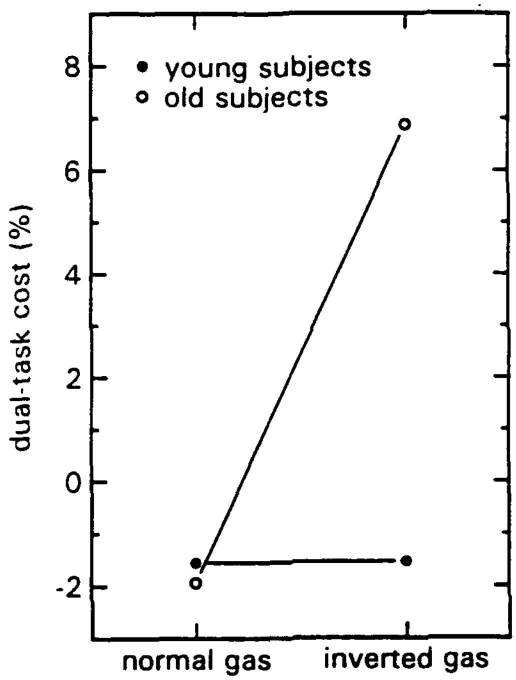

Fig. 4 Dual-task costs on steering performance of both age groups, as affected by Gas Control Novelty.

Car-following performance

With respect to car-following performance, dual-task costs were analyzed in a 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) ANOVA. This analysis provided no main or interaction effects. Although, both age groups were clearly hampered by the dual-task requirements related to their single-task performances (24 % performance deterioration), these effects were equal and unaffected by Novelty and Difficulty Alternation. Together with the steering performance data, these results clearly confirm the findings of Schneider and Fisk (1982), indicating that controlled processes are more easily disrupted by simultaneous automated processes than *vice versa*. Furthermore, the clear negative effects of an automated task on a controlled task is not affected by age, nor by whether or not the latter task is developed before or after old age. Figure 5 shows the trade-off between the automated and controlled task for both age groups.

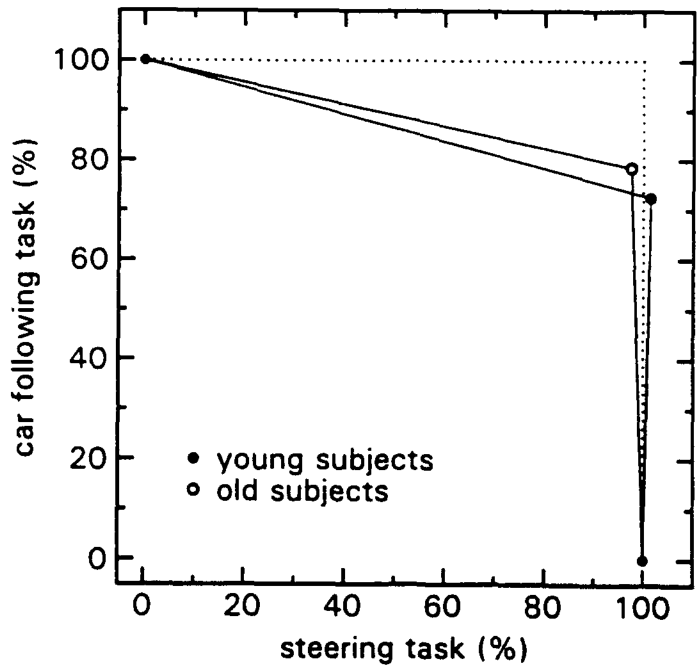

Fig. 5 Performance operating characteristics for the young and the old group. Each point in these graphs represent one condition. From left to right: the car-following task without the requirement to steer, the dual-task, and steering task without the requirement to control speed.

3.3 Training or fatigue effects

In pilot studies, it was determined how much practice was required in order to reach a stable task performance for both age groups. This amount of training was given in the present experiment. In order to check if this amount indeed had been enough, ANOVA's were carried out in which Block Number was incorporated as a variable.
With respect to steering performance a 2 (Age) x 2 (Difficulty Alternation) x 2 (Block Number) ANOVA on the single task data showed a significant effect of Block Number, $F(1,22) = 4.2$, $p < .05$. However, this effect was contrary to a training effect; subjects performed worse in the second experimental block. Presumably, this was a fatigue effect. This effect was equal for both groups, but it interacted with Difficulty Alternation, $F(1,22) = 16.6$, $p < .001$. Fig. 6 shows that the fatigue effect was only evident in the conditions with alternating task difficulty. The lower steering performance in the second block only for the conditions with alternating task difficulty is difficult to explain, and may be a consequence of chance capitalization.
A 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) x 2 (Block Number) ANOVA on dual-task costs in steering performance did not show any significant main or interaction effects of Block Number.

In conclusion, in accordance with the idea that the steering task could be performed in an automatic mode, subjects did not show training effects.

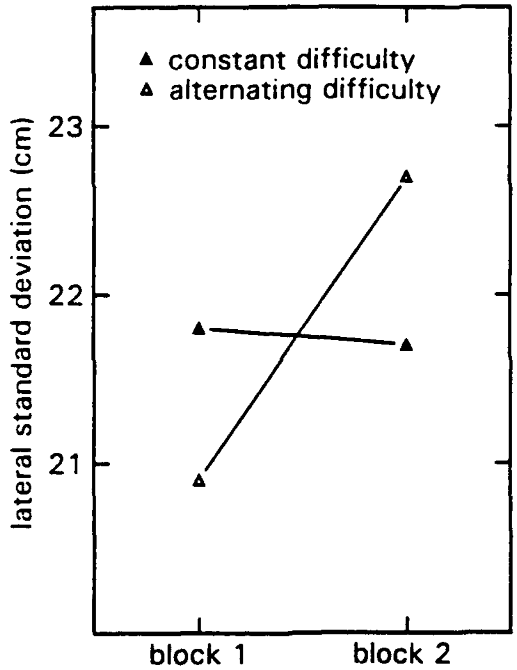

Fig. 6 Single-task steering performance of the subject group as a whole, as affected by Difficulty Alternation and Block Number.

With respect to single-task car-following performance, training or fatigue effects were analyzed in a 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) x 2 (Block Number). This ANOVA only showed one marginal interaction of Block Number with Novelty ($p < .10$). This interaction suggests that subjects tended to deteriorated task performance with increasing practice when subjects were familiar with gas pedal functioning, while task performance tended to increase with practice when the gas pedal was inverted (Fig. 7). This indicates that with respect to the atypical gas response, subjects may not have been completely trained. These effects, however, are small and not very reliable.

As was the case for steering performance, a 2 (Age) x 2 (Novelty) x 2 (Difficulty Alternation) x 2 (Block Number) ANOVA on dual-task costs in car-following performance did not show any significant main or interaction effects of Block Number.

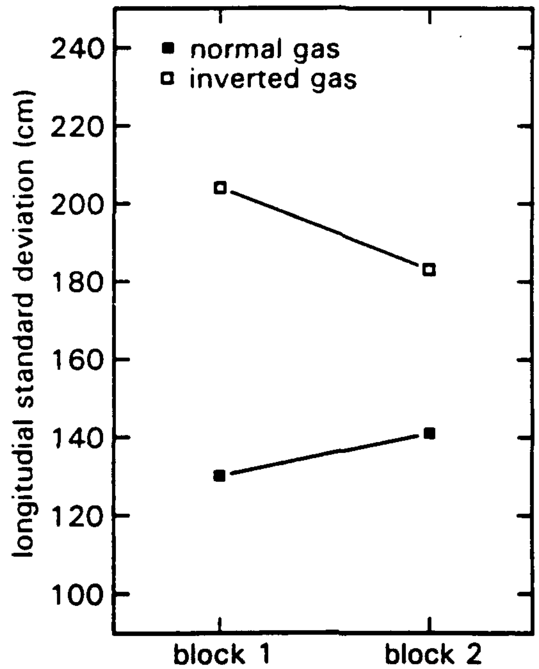

Fig. 7 Single-task car-following performance of the subject group as a whole, as affected by Gas Control Novelty and Block Number.

In summary, there was only one small training effect in single-task performance, suggesting that subjects were not completely trained with respect to the unfamiliar car-following task. Furthermore, there were no age-related differences, neither in sequential effects nor in dual-task performance.

4 DISCUSSION

Hasher and Sacks (1979) have argued for age independence in tasks requiring automatic processing. In contrast, Fisk et al. (1988) have found that with increasing age, the likelihood that extended practice will lead to automatic processing, is reduced. According to Fisk et al. (1988) and Fisk and Rogers (1991), the apparent difference between these findings can be reconciled by making a distinction between the development of automatic processing on the one, and its use on the other hand. Automatic processing developed prior to old age, may remain effective when old age is reached. With reference to this topic, the single-task results show that age-decrements disappear when well learned controlled as well as automatic skills were developed before old age. That is, for steering and car-following with normal gas control, both previously developed, age-effects were absent, whereas car-following with inverted gas pedal functioning produced a substantial age effect. With respect to controlled processes developed after old age, the single-task data showed that reversal of the gas pedal did not affect task performance of the young (equal task complexity), whereas the older subjects clearly were hampered by this manipulation. Apparently, the fact that a skill is developed and used in the same period does not bother at all when subjects are young, whereas in old age, it makes a lot of a difference. This finding means that previously developed automatic processes, but also well-trained controlled processes do not diminish with age. Hence, the data suggest that with regard to age differences, period of skill development is more crucial than processing mode.

The slowing-complexity hypothesis predicts that the magnitude of age-differences is proportional to the complexity of the task (in terms of the young subjects' performances). This means that the effect of Novelty on the older subjects was in conflict with the slowing-complexity hypothesis, which would not predict an age-difference in the car-following condition because the young subjects were not hampered by gas reversal.

In the dual-task conditions, steering performance of the older subjects only was deteriorated, if in the extra controlled car-following task, gas pedal functioning was inverted. Hence, for older adults, automated processes may be disrupted by a controlled task, but only when this controlled task was exclusively practised in old age. Therefore, the data support the hypothesis that for older subjects, dual-task performance may become poorer when at least one of the subtasks is not well-trained before old age. These results substantiate earlier findings, which also seem to contradict the notion of age independence in automated processing. Moore, Richards, and Hood (1984) found a significant deterioration with age in a "memory for location" test, which is regarded to be based on characteristics that are encoded automatically.

With respect to dual-task steering performance, the young subjects showed that both conditions of novelty of the extra task were equally complex. Therefore, the Age x Novelty interaction, showing an age deterioration only when steering was combined with the novel car following situation, is not predicted by, and thus incompatible with, the slowing-complexity hypothesis.

With respect to car-following, both age groups were clearly and equally hampered by the dual-task requirements (24 % performance deterioration relative to single-task performance). This effect was unaffected by Novelty and Difficulty Alternation. Together with the steering performance data, these results confirm the findings of Schneider and Fisk (1982) with student subjects, indicating that controlled processes are more easily disrupted by simultaneous automated processes than *vice versa*. Now it can be concluded that the tendency to waste controlled resources on automatic processing tasks seems not to be different for non-students or for older subjects. Furthermore, the negative effects of an automated task on a controlled task is not affected by age, nor by whether or not the latter task is developed before or after old age. Negative effects of age only seem to be limited to the smaller effects in the automated task performed in combination with a novel controlled task.

It has been demonstrated that age differences are increased by task variables that emerge from the relationship between subtasks (Korteling, 1991, 1993). This may be related to age decrements in attention switching, prioritizing information from multiple sources, and combining related actions. In this connection, the presnet experiment aimed at effects determined by whether or not the difficulty levels of subtasks were alternating in counter-phase. It was expected that old and young subjects would differ in the degree to which they are capable to sequentially distribute attention in proportion to the relative difficulty of the subtasks. Unexpectedly, however, this variable did not affect task performance at all. Apparently, both subject groups were equally well able to switch and distribute attention according to the relative subtask demands. Also in single-task performance, the sequential change of difficulty levels did not affect task-performance. This may be explained by a notion of Craik (1991), who suggested that age effects usually are the greatest when subjects cannot rely on environmental support or general knowledge. According to Craik, age-effects often disappear when subjects are not required to initiate actively supervisory strategies for performance optimalization. In connection with this notion, the complete absence of (counterphase) difficulty alternation effects suggests that this variable probably was evidently imposed and supported by the task. In other words: self-initiated supervisory attention may not have played a significant role in the present experiment. Moreover, the absence of relevant effects shows that the older did not suffer significantly from a deteriorated flexibility in distributing attention and effort between subtasks.

An intriguing outcome of the present experiment is the differential effect on age-related performance differences of Novelty, e.i., whether or not skills have been previously developed; an effect that also dominated over the supposed differential effects of processing mode (Hasher and Sacks, 1979). Most laboratory experiments on aging research are based on new tasks, which means that the relevant skills must be learned and used in the same period. However, most skills required in jobs and in private activities are developed in earlier periods of adulthood. Therefore, the majority of prevailing laboratory results should not be generalized too easily to practical situations. Nevertheless, in dual-task performance, age effects were solely found in the automated task when combined with the controlled task that was trained *after* old age.

What may be concluded with respect to a complex everyday task, such as car driving, consisting of numerous subtasks and involving consistent and inconsistent relationships among stimuli? The skills involved in car driving range from elementary low-level ("control"), to medium-level ("manoeuvre"), to complex high-level ("strategical") skills (e.g., Michon, 1971; Janssen, 1979). From low-level to high-level subtasks, the degree of automaticity and task priority may be supposed to decrease (Korteling, 1988). The present conclusions are based on a simulator experiment with steering as a control skill, and car-following as a manoeuvre skill. With respect to car driving, we may conclude: 1) that age-effects are absent in single automated control tasks, 2) that negative age-effects in manoeuvre tasks increase when the task becomes unfamiliar, 3) that in situations requiring simultaneous actions, people tend to give priority to control subtasks over manoeuvre subtasks, and 4) that nevertheless in these situations, older people cannot maintain optimal control performance when the manoeuvre task is unfamiliar.

In the study of Schneider and Fisk (1982), subjects were capable of doing the dual-task without noticeable deficit when they were encouraged to place all emphasis on the controlled task. Therefore, they conjectured the tendency of giving priority to automatic subtasks to be a *waste* of resources. Since in vehicle control, the execution of a low-level subtask is regarded an essential border condition for the execution of higher-level subtasks (Korteling, 1988), one should be cautious to draw these kinds of conclusions with regard to tasks like car driving. The present results suggest that the problems older drivers encounter (e.g., Brainin, 1980; McFarland, Tune and Welford, 1964; Planek and Fowler, 1971), may not be caused by the *invariant* components of the driving task, which usually are well-learned long before old age. These problems may merely occur in novel situations, such as removal to another city, changing regulations, changing layouts of intersections, or the purchase of a new car.

The most significant conclusion of the present experiment, i.e., that age-effects appear when subjects cannot use skills that previously have been extensively trained, is in line with the every-day experience that the acquisition of well-trained perceptual-motor skills, such as music playing, car driving, or typewriting, appear to require much more effort as people grow older. In music playing, for example, this effect already starts in childhood. Therefore, this kind of diminishing automaticity development with increasing age may be considered one aspect of a universal trend in physiological and behavioral development. This trend goes from neuronal plasticity and differentiation, associated with behavioral flexibility and adaptation, to neuronal inertness and stabilization (eventually overshadowed by degeneration), associated with functional specialization and behavioral rigidity. This presumed gradual process of human ontogenesis also signifies that the concept of "old age" and whether or not a skill is developed before or after this life period is equivocal. The present results may thus be regarded to reflect a pervasive, but also indistinct, tendency towards decreased psycho-motor learning capabilities in later adult life.

REFERENCES

Birren, J.E., Woods, A.M. & Williams, M.V. (1980). Behavioral slowing with age: causes, organization, and consequences. In L.W. Poon (Ed.). Aging in the 1980s (pp. 293-308). Washington, D.C., American Psychological Association.

Brainin, P.A. (1980). Safety and mobility issues in licensing and education of older drivers. Report no. DOT-HS-805 492. Darien, CT: Dunlap and Ass., Inc.

Broadbent, D.E. & Gregory, M. (1965). Some confirmatory results on age differences in memory for simultaneous stimulation. British Journal of Psychology, 56, 77-80.

Brookhuis, K.A., de Vries, G. & de Waard, D. (1989). De effecten van het gebruik van de autotelefoon op het rijgedrag. Rapport VK 89-02, Verkeerskundig Studiecentrum, Haren, The Netherlands.

Brown, I.D., Tickner, A.H. & Simmonds, D.V.C. (1969). Interference between concurrent tasks of driving and telephoning. Journal of Applied Psychology 53, 419-424.

Caird, W.K. (1966). Aging and short-term memory. Journal of Gerontology, 21, 295-299.

Cerella, J., Poon, L. & Williams, D. (1980). Age and the complexity hypothesis. In: L. Poon (Ed.) Aging in the 1980s. Washington DC, American Psychological Association,

Clark, L.E. & Knowles, J.B. (1973). Age differences in dichotic listening performance. Journal of Gerontology, 28, 173-178.

Craik, F.I.M. (1965). The nature of the age decrement in performance on dichotic listening tasks. Quarterly Journal of Experimental Psychology, 17, 227-240.

Craik, F.I.M. (1991). Memory and learning. Paper presented at Gerontechnology, First International Conference on Technology and Aging, Eindhoven University.

Duncan, J. (1979). Divided attention: the whole is more than the sum of its parts. Journal of Experimental Psychology: Human Perception and Performance, 5, 216-228.

Fisk, A., Ackerman, P.L. & Schneider, W. (1987). Automatic and controlled processing theory and its applications to human factors problems. In P.A. Hancock (Ed), Human factors psychology (pp 159-197). New-York: North Holland.

Fisk, A.D., Oranski, N.A. & Skedsvold, P.R. (1988). Examination of "higher-order" consistency in skill development. Human Factors 30, 567-582.

Fisk, A.D., McGee, N.D. & Giambra, L.M. (1988). The influence on consistent and varied semantic-category search performance. Psychology and Aging, 3, 323-333.

Fisk, A.D., Rogers & W.A. (1991). Development of skilled performance: An age-related perspective. In D.L. Damos (Ed), Multiple Task Performance (pp 415-443). London-Washington: Taylor & Francis.

Fracker, M.L. & Wickens, C.D. (1989). Resources, confusions, and compatibility in dual-axis tracking: displays, controls, and dynamics. Journal of Experimental Psychology: Human Perception and Performance, 15, 80-96.

Hale, S., Myerson, J. & Wagstaff, D. (1987). General slowing of nonverbal information processing: Evidence for a power law. Journal of Gerontology, 42, 131-136

Hasher, L. & Zacks, R.T. (1979) Automatic and effortful processes in memory. Journal of Experimental Psychology: General, 108, 356-388.

Inglis, J. & Ankus, M.N. (1965). Effects of age on short-term storage and serial rote learning. British Journal of Psychology, 56, 183-195.

Inglis, J. & Caird, K.W. (1963). Age differences in responses to simultaneous stimulation. Canadian Journal of Experimental Psychology, 17, 78-105.

Janssen, W.H. (1979). Routeplanning en -geleiding: een literatuurstudie. Report IZF 1979 C-13, TNO Institute for Perception, Soesterberg, the Netherlands.

Klapp, S.T. (1979). Doing two things at once: The role of temporal compatibility. Memory & Cognition, 9, 398-401.

Korteling, J.E. (1988). Informatieverwerking van oudere verkeersdeelnemers. Rapport IZF 1988-9. Instituut voor Zintuigfysiologie TNO, Soesterberg.

Korteling, J.E. (1991). Effects of skill integration and perceptual competition on age-related differences in dual-task performance. Human Factors, 33, 35-44.

Korteling, J.E. (1993). Effects of age and task similarity in dual-task performance. Human Factors, in press.

Logan, G.D. (1978). Attention in character classification tasks: evidence for the automaticity of component stages. Journal of experimental Psychology: General 107, 32-63

McDowd, J. (1986). The effects of age and extended practice on divided attention performance. Journal of Gerontology, 41, 764-769.

McDowd, J. & Craik, F.I.M. (1988). Effects of task difficulty on divided attention performance. Journal of Experimental Psychology: Human Perception and Performance, 14, 267-280.

McFarland, R.A., Tune, C.S. & Welford, A.T. (1964). On the driving of automobiles by older people. Journal of Gerontology, 19, 190-197.

Madden, D.J. & Nebes, R.D. (1980). Aging and the development of automaticity in visual search. Developmental Psychology, 16, 377-384.

Meyerson, J., Hale, S., Wagstaff, D., Poon, L.W. & Smith, G.A. (1990). The information -loss model: a mathematical theory of age-related cognitive slowing. Psychological Review, 97, 475-487.

Michon, J.A. (1971). Psychonomie onderweg. Inaugural address. Groningen: Wolters-Noordhoff.

Moore, T.E., Richards, M.A. & Hood, J. (1984). Aging and the coding of spatial information. Journal of Gerontology, 39, 210-212.

Navon, D. & Miller, J. (1987). The role of outcome conflict in dual-task interference. Journal of Experimental Psychology: Human Perception and Performance, 13, 435-448

Peters, M. (1977). Simultaneous performance of two motor activities: the factor timing. Neuropsychologia, 15, 461-465.

Planek, T.W. & Fowler, R.C. (1971). Traffic accident problems and exposure characteristics of the aging driver. Journal of Gerontology, 26, 224-230.

Ponds, R.W.H.M., Brouwer, W.H. & Wolffelaar, P.C. van (1988). Age differences in divided attention in assimilated driving task. Journal of Gerontology, 43, 151-156.

Posner, M.I. & Snyder, C.R.R. (1975). Attention and cognitive control. In R.L. Solso (Ed). Information Processing and Cognition: The Loyola Symposium (pp 55-85). Hillsdale, N.J.: Erlbaum.

Salthouse, T.A. (1982). Adult cognition: An experimental psychology of human aging. New York: Springer-Verlag.

Salthouse, T.A. (1985). A Theory of Cognitive Aging. Amsterdam: North-Holland.

Salthouse, T.A. (1990). Influence of experience on age differences in cognitive functioning. Human Factors, 32, 551-559.

Salthouse, T.A, Rogan, J.D. & Prill, K. (1984). Division of attention: age differences on a visually presented memory task. Memory and Cognition 12, 613-620.

Schneider, W. & Fisk, A.D. (1982) Concurrent automatic and controlled visual search: can processing occur without resource cost? Journal of Experimental Psychology, Learning, Memory, and Cognition, 8, 261-278.

Somberg, B.L. & Salthouse, T.A. (1982). Divided attention abilities in young and old adults. Journal of Experimental Psychology, Human Perception and Performance, 8, 651- 663.

Schneider, W. & Detweiler, M. (1988). The role of practice in dual-task performance: Toward workload modelling in a connectionist/control architecture. Human Factors, 30, 539-566.

Schneider, W. & Shiffrin, R.M. (1977). Controlled and automatic human information processing. I: Detection, search, and attention. Psychological Review 84, 1-66.

Shiffrin, R.M. & Schneider, W. (1977) Controlled and automatic human information processing. II: Perceptual learning, automatic attending, and a general theory, Psychological Review 84, 127-190.

Shiffrin, R.M. & Schneider, W. (1984). Theoretical note, automatic and controlled processing revisited. Psychological Review, 91, 269-276.

Talland, G.A. (1962). The effect of age on speed of simple manual skill. Journal of Genetic Psychology, 100, 69-76.

Verwey, W.B.V. (1991). Toward guidelines for in-car information management: driver workload in specific driving situations. Report IZF 1991 C-13, TNO Institute for Perception, Soesterberg, the Netherlands.

Welford, A.T. (1958). Aging and human skill. London: Methuen Press.

Welford, A.T. (1965). Performance, biological mechanisms and age: a theoretical sketch. In A.T. Welford & J.E. Birren (Eds.), Behavior, Aging and the Nervous System (pp. 3-20). Springfield, Illinois, C.C. Thomas.

Welford, A.T. (1977). Motor performance. In J.E. Birren & K.W. Schaie (Eds.), Handbook of the Psychology of Aging (pp 450-496). New York, Nostrand Reinhold.

Wickens, C.D. (1989). Attention and skilled performance. In D.H. Holding (Ed). Human Skills (pp 71-105). Chichester: Wiley & Sons.

Wickens, C.D. (1992). Engineering Psychology and Human Performance. London: Harper Collins.

Wierda, M. & Brookhuis, K.A. (1991). Analysis of cycling skill: a cognitive approach. Applied Cognitive Psychology, 5, 113-122.

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15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

The magnitude of age effects in single- and dual-tasks may be affected by the degree to which the tasks require automatic or controlled processing (Hasher and Sacks, 1979) and whether skills of older subjects are familiar and developed before old age or novel and developed during the experiment (Fisk, McGee and Giambra, 1988). In addition, age-effects may be affected by emergent dual-task characteristics (Korteling, 1991, 1992), and by overall task complexity ("Complexity hypothesis" e.g., McDowd and Craik, 1988). Effects of the first three task variables were addressed in an experiment, in which experienced subjects performed a vehicle steering task (automatic processing) and a car following task (controlled processing) in a driving simulator. The controlled task was performed under two conditions of Novelty. In one condition, the gas pedal functioned normally (skill development before old age), while in the other condition it functioned in an inverted way. This implies that the subjects only practised this latter task condition during the experiment (skill development after old age). In dual-task performance, difficulty of both subtasks was constant or variable. In the latter case, subtask difficulty alternated in counterphase. The single-task results indicated that the older subjects performed poorer than their younger counterparts only in the car-following task, with an invertedly functioning gas pedal. Also in dual-task performance, an age-effect was found when this controlled task was performed with inverted gas pedal functioning. In that case, the age-effect was found in the automatic subtask. In conclusion: in automatic and in controlled processing tasks as well, age-effects appear when subjects can not utilize skills that were previously developed. Dual-task costs were basically manifested in the controlled task. Counterphase difficulty alternation did not affect task performance at all, which may be explained by the fact that this variation probably was so clearly imposed by the task, that adequate behavioral adaptations automatically were elicited. Post-hoc interpretations of the data indicated that these were not completely consistent with the complexity hypothesis.

16. DESCRIPTORS	IDENTIFIERS
Age	Age
Perceptual-motor skills	Driving
Task complexity	Dual-task performance
Vehicle driving	Processing speed
	Simulators
	Task integration

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