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EFFECTS OF AGE AND TASK INTEGRATION ON DUAL TASK PERFORMANCE

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Effects of age and task integration on dual task performance

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SUMMARY

An earlier experiment showed that in a dual task older adults do not benefit from stimulus synchronization as much as younger subjects do. Only young subjects were able to combine skills for separate subtasks into more integral dual task skills. This integration of skills is only possible when subtasks are connected or related. On other words: in order to be able to integrate skills integration of the task ("task integration") is a necessary condition.
However, task integration may also hamper task performance. This is supposed to be the case when the compatibility between stimulus and response decreases or when subtasks become too similar to keep them sufficiently separate (e.g. combining different functions at one control stick). This will cost more processing capacity to map subtask stimuli to the proper responses. If older people have difficulties with these mapping operations task integration may impede their task performance.
In the present experiment this issue was addressed with a dual task consisting of two one-dimensional compensatory tracking tasks with perpendicular tracking axes. Based on independent manipulations of display and joystick integrality the dual task was carried out under four conditions of compatibility. One condition was also carried out with tracking axes in line. This increasing task similarity of subtasks was supposed to make it more difficult to keep the subtasks separate, causing interference or "cross talk" in task performance.
Data reflecting general tracking performance were consistent with the hypothesis that older subjects are extra penalized when task integration decreased the degree of compatibility of integrality. The cross talk data were only consistent with the compatibility of integrality hypothesis in the conditions with an integrated joystick. The idea that incompatibility of integrality should consume extra resources (decreasing movement speed), also was only supported in the conditions with an integrated joystick. All performance measures (tracking performance, axis cross talk, and movement speed) supported the hypothesis that with increasing subtask similarity performance of older people is degraded. Cross talk was significantly correlated with processing speed. Processing speed, however, was not found to be correlated with indices reflecting other pure dual task skills (general tracking performance and movement speed decrement). Theoretical and practical implications of these findings are discussed.

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Effecten van leeftijd en taakintegratie op dubbeltaak-prestaties

J.E. Korteling

SAMENVATTING

Een eerder experiment liet zien dat ouderen in een dubbeltaak relatief slecht gebruik maken van stimulus synchronisatie. Alleen jongere proefpersonen bleken in staat vaardigheden voor de twee onderscheiden taken te combineren tot één meer integrale dubbeltaak-vaardigheid. Deze integratie van vaardigheden is alleen mogelijk als de subtaken overeenkomstige eigenschappen hebben. Met andere woorden: voor het kunnen integreren van vaardigheden is integratie van de taak ("taakintegratie") een noodzakelijke voorwaarde.
Echter, taakintegratie kan de taakuitvoering ook bemoeilijken. Dit kan gebeuren doordat de stimulus-respons compatibiliteit in de dubbeltaak afneemt of doordat de deeltaken zoveel op elkaar gaan lijken dat het moeilijk wordt ze uit elkaar te houden (bv. het samenvoegen van verschillende bedieningsfuncties op één hendel). Het kost dan meer moeite, en daarmee verwerkingscapaciteit, de stimuli voor de subtaken en de bijbehorende handelingen goed op elkaar af te stemmen. Indien ouderen hiermee problemen hebben zullen een aantal vormen van taakintegratie hun prestaties sterk belemmeren.
Bovenstaande hypothesen werden getoetst met een dubbeltaak bestaande uit twee ééndimensionale compensatoire stuurtaken met loodrechte stuurassen. Op basis van onafhankelijke variaties van beeldscherm- en joystick integraliteit werd de taak uitgevoerd onder vier condities van compatibiliteit. Eén conditie werd tevens uitgevoerd met de stuurassen in elkaars verlengde. Verwacht werd dat deze toenemende gelijkenis van subtaken de kans op verwarring groter maakte.
Data betreffende de stuurprestaties van proefpersonen waren consistent met de hypothese dat ouderen extra gehinderd worden wanneer taakintegratie leidt tot een lagere stimulus-respons compatibiliteit. De cross-talk data ondersteunden de compatibiliteit hypothese alleen in de condities met geïntegreerde joysticks. De suggestie dat incompatibiliteit extra verwerkingscapaciteit kost (afnemende beweegsnelheid) werd eveneens alleen bevestigd in de condities met een geïntegreerde joystick. Alle prestatiematen ondersteunden de hypothese dat de prestatie van ouderen relatief sterk achteruitgaat bij toenemend gelijkenis van subtaken. Overspraak correleerde significant met verwerkingssnelheid. Snelheid bleek echter niet te correleren met andere zuivere dubbeltaak prestatiematen (stuurprestatie en afname van beweegsnelheid). Aan het slot worden theoretische en praktische implicaties van het bovenstaande besproken.

1 INTRODUCTION

The chance of being involved in a serious traffic accident increases with age (e.g. Brainin, 1980). One of the possible causes for this increasing risk is a deterioration in psychological functioning. Since the number of older traffic participants will substantially increase in the coming decades, more knowledge of the nature and causes of psychological decline with age is necessary to increase the mobility and safety of older road users. Therefore the Ministry of Transport and Public Works in the Netherlands supports research into age-related functional decline.

A survey of the literature (Korteling, 1988) showed that older people exhibit a variety of functional deteriorations, which may have serious consequences for traffic behaviour. One of these deteriorations was shown by large performance differences between older and younger subjects in dual tasks (Boer, 1986; Broadbent & Gregory, 1965; Clark & Knowles, 1973; Craik, 1965; Inglis & Caird, 1963; Korteling, 1989, Korteling & Burry, 1989; Ponds, Brouwer, & Van Wolffelaar, 1988; Salthouse, Rogan & Prill, 1984; Talland, 1962; Wright, 1981). In dual tasks subjects have to perform two tasks at the same time. Since traffic participants often are involved in two or more simultaneous activities, traffic tasks may also be regarded as dual tasks. For example, car drivers have to manipulate the steering wheel and the gear handle while watching the traffic situation at the same time. Also bicyclists and pedestrians have to perform simultaneous motor and perceptive actions.

Therefore a series of experiments is conducted to get more insight into the causes of decreased performance on dual tasks with age. Earlier experiments were based on a dual task paradigm involving two one-dimensional compensatory tracking tasks with orthogonal tracking axes. The first experiment (Korteling, 1989) showed that the young outperformed the older subjects only when the pointers of both sub-tasks made synchronous movements (task synchronization). Besides, only the young benefitted from task synchronization in order to overcome the negative effects of visual competition. The older subjects were not capable to do this. Apparently, synchronization of subtasks enabled only the young to integrate these separated activities. It was concluded that only the young were able to combine separate actions for both subtasks into more integral actions for dual task performance ("skill integration", Neumann, 1987).

For many dual tasks it remains unclear why older people show problems. Is it a transient effect, caused by slower learning of new tasks, or are there more stable and structural changes in information processing explaining this age-effect? To address this issue a follow-up experiment was carried out (Korteling & Burry, 1989) in which the tracking tasks were repeatedly practised. This experiment demonstrated that the advantage of the younger subjects with synchronized subtasks was not caused by an inability of older subjects to learn new (dual task) skills. Therefore it was concluded that the older subjects' inability of skill integration was due to structural changes in information processing.

If subtasks are completely independent or completely different, it may be impossible to combine actions in order to perform the dual task in an integrated, or coordinated manner[1]. Therefore integration of skills for subtasks seems only possible when subtasks are related, or dependent, to some degree with reference to stimulus information, required processing operations, and/or responses. When task integrality is conceived as the degree to which subtasks are related, the above implies that skill integration is facilitated by increasing task integrality. Increasing the degree of task integrality may be termed task integration. The more a time sharing task is integrated the less the task may be performed (and experienced) as a dual task. For example, skilled oral reading requires a span of several words between the subtasks reading and speaking, yet for many people skills for oral reading are integrated to such a high degree that it is hardly experienced as dual task performance.

The facilitation of skill integration by task integration may be conceived as a natural way to improve task performance, to overcome interference between activities, and to reduce attentional demands. However, task integration may also hamper performance. This is evidently so when integration causes subtasks to be dependent on the same processing faculties, the scarce entities or processing mechanisms needed for task performance (e.g. Wickens, 1984). When two tasks become dependent on the same processing faculties, one may expect that dual task performance is degraded by the constraints of these limited-capacity mechanisms.

Performance may also be degraded when task integration is unequal for the stimulus and response parts of the dual task, such that the integrality of subtasks at the stimulus level becomes different from that at the response level. For example: partial task integration only directed to the response part (e.g. combining different functions at

[1]When subtasks are completely independent improved performance may only be achieved by improving skills for single task performance, e.g. automatic processing.

one control stick) may disturb the natural relationship between stimulus information and accessory actions. This may cause what Fracker & Wickens (1989) call "incompatibility of integrality". In a dual tracking task incompatibility of integrality may be seen when two one-dimensional pointers (low integrality) have to be controlled with one two-dimensional control stick (high integrality). Furthermore, task integration may hamper performance when subtasks become more similar such that it becomes more difficult to keep subtasks separate. Actions relevant for one subtask may then easily be directed to the wrong subtask, or perceptual and motor operations for subtasks may be confounded. When task integration decreases the compatibility of integrality or makes subtasks more similar the subject is required to perform extra, or more precise mapping operations between stimuli and responses, such that subtasks and actions become properly matched.

If older people have difficulties with these mapping operations at least some kinds of task integration will be detrimental to their task performance. Evidence for an age-related mapping problem has been found for single tasks, like pursuit rotor tasks, in which spatial transpositions had a disproportionately adverse effect on older people (e.g. Ruch, 1934). Mapping operations may degrade dual task performance for two reasons. First, when people fail to make the proper mapping operations confusion may result, e.g. perceptive or control actions may interfere or be directed to the wrong subtask ("cross talk"). In a dual axis tracking task axis cross talk will probably be the greatest whenever it is most difficult to separate the subtasks (Fracker & Wickens, 1989). Second, mapping operations may consume extra resources. This extra demand leaves less resources for effective task performance (see Navon & Gopher, 1979 for a theoretical discussion).

Probably the most well-known universal hypothesis for increased performance differences between age groups on dual tasks is based on the notion that aging is accompanied by general slowing in information processing (Salthouse, 1982, 1985). This general slowing causes performance differences between age groups to increase with task complexity ("slowing-complexity" hypothesis, Cerella, Poon & Williams, 1980). In these terms the substantial age-related performance differences on dual tasks is assumed to be caused by the mere complexity of these tasks and nothing else (e.g. McDowd & Craik, 1988). However, the results of a prior dual tracking experiment (Korteling & Burry, 1989) were not consistent with the slowing-complexity hypothesis. Information processing speed (which was found to be correlated with axis cross talk) was not related to specific dual task skills.

In order to analyze the implications of the universal slowing-complexity hypotheses and to test the more specific effects of mapping demands on age-effects the present experiment addressed the following hypotheses:

- When dual tasks require extra, or more precise, mapping operations between display information and control actions, age-effects in task performance will increase.
- When general slowing is a major cause of age effects in dual tasks, processing speed will be correlated with pure dual task performance measures.

The experiment was carried out with two simple one-dimensional tracking tasks with perpendicular tracking axes. Mapping requirements were supposed to increase when subtasks were only partially integrated. More complete separation or integration of the subtasks was supposed to increase compatibility of integrality and thus limit mapping requirements. Therefore display and joystick integrality were independently varied. In order to address the idea that increasing similarity between subtasks requires more precise mapping operations, subtask similarity was also manipulated. Therefore the experiment was extended with one condition in which the tracking axes were lined up.
Dependent variables consisted of three single task speed measures and three dual task measures. Three single task measures were supposed to reflect information processing speed.

1 ***Tracking performance*** which is based on quick responding on pointer movements relative to a fixed target.
2 ***Compensatory movement speed*** which is based on the frequencies of pointer movements.
3 ***Digit Symbol Substitution***, a paper and pencil test of the Wechsler Adult Intelligence Scale (WAIS), which is often highly recommended as a reliable, age-sensitive, and simple index of an individual's general rate of information processing (e.g. Salthouse, 1985).

In the dual task conditions three dependent variables were analyzed, all reflecting pure dual task performance.

4 ***Dual task tracking performance***, individually calibrated for single task tracking performance, was used as a general index of dual task skill.
5 ***Cross axial correlations***, the correlations between the error signals of the two tracking axes, reflected the degree to which independently disturbed pointer movements were made dependent by the tracking actions of the subjects. When both tracking axes are perpendicular the relationship between stimuli and control actions for both tasks is atypical. Therefore it should more depend on

individual idiosyncrasies than on task variables whether correlations turn out to be positive or negative. Thus, cross talk in the condition with perpendicular tracking axes may be supposed to show up in only the *absolute* correlations between the error signals. In the condition with tracking axes in line, however, the sign of the correlations between tracking axes made sense. When subjects direct control actions to the wrong axis (or to both axes at the same time) or subjects perform poorer when pointers are on a different side of their target correlations will be negative. If subjects perform poorer when the pointers are on the same side of the targets correlations will be positive.

6 ***Dual task speed decrement***, the difference in movement speed between each dual task tracking axis and the relevant single task axis. As processing resources come under increasing demand, subjects are often found to decrease the speed of their control movements, probably in order to reduce the chance that an incorrect movement will cause them to lose control of the system. Therefore movement speed decrement was used as an index for the extra demand of resources caused by pure dual task requirements.

2 METHOD

2.1 Subjects

A total of 28 subjects divided into two groups of ten males and four females participated in the experiment. Due to equipment problems the data of two subjects were incomplete and thus left from consideration. The mean age of the older subjects was 70 (range 64-77, sd 4.3); the mean age of their younger counterparts was 26 (range 19-30, sd 3.2). The subjects were matched on educational and (ex-) professional level. All subjects were healthy at the time and had normal or corrected to normal visual acuity.

2.2 Experimental task and apparatus

The dual axis compensatory tracking tasks were constructed out of two independent single axis compensatory tracking tasks.

Control sticks
Two analog control sticks (joysticks) were positioned in front of the subject on a horizontally mounted panel. Subjects had to null vertical and horizontal errors by using either separate controls for each axis or a single integrated control for both. When a control was integrated it was located to the subjects' preferred hand and could be manipulated in two dimensions. Otherwise the control was constrained to move only in one dimension. In the single task conditions error also could be controlled in only one axis. Horizontal deflections of the controls always controlled error in the horizontal axis and fore and aft deflections controlled vertical error (see Fig. 1).

Display
Subjects were seated at a distance of approximately 140 cm from a RGB high resolution monitor (Barco). The pointer on the screen was a dot diagonally 0.07°. The inside diameter of the target circle was 0.6°. On the screen one integrated pointer was disturbed in two dimensions at the same time or two separated pointers moved in one dimension at the same time. When pointers were separated the visual angle between the two stationary targets (Fig. 1) was 2.8°. Structural visual interference effects were supposed to be minimal since this angle would keep the pointers within the stationary field of the eyes. Sanders showed that stimuli within the stationary field are simultaneously processed (e.g. Sanders 1963; Sanders & Houtmans, 1984). For the single axis tasks only one pointer moved in one dimension.

System dynamics and disturbance inputs
In all experimental conditions a 1° rotation of the control resulted in a .26° translation of the pointer on the screen (position control). Error was created by disrupting pointers by a band limited (frequency < 1 Hz), pink noise forcing function. This function was the same for all subjects and consisted of 18000 points computed before the experiment. To allow continuous transgression when the end was reached the beginning and the end of the track were adjusted. For each experimental trial the starting point within the track was chosen randomly. In the dual task conditions the starting points of both subtasks differed by 9000 points. Error was sampled and stored for analysis with 50 Hz. Experimental control and data acquisition were governed by an IBM AT personal computer.

Experimental variables
For each age group four conditions were created by two levels of the factor "control integrality" combined with two levels of the factor

"display integrality". Display integrality was varied by using two separate pointers moving in one direction or integrating them into one pointer moving in two dimensions. Joystick integrality was varied by using two single axis joysticks or integrating them into one dual axis joystick. A fifth condition was created which consisted of separated pointers and controls both lined up horizontally (see Fig. 1). As mapping requirements were supposed to increase with subtask similarity (making it difficult to separate the subtasks) the latter condition with identical tracking axes was added. The single task design consisted of four conditions formed by the factorial combination of hand (left, right) and tracking axis (horizontal, vertical).

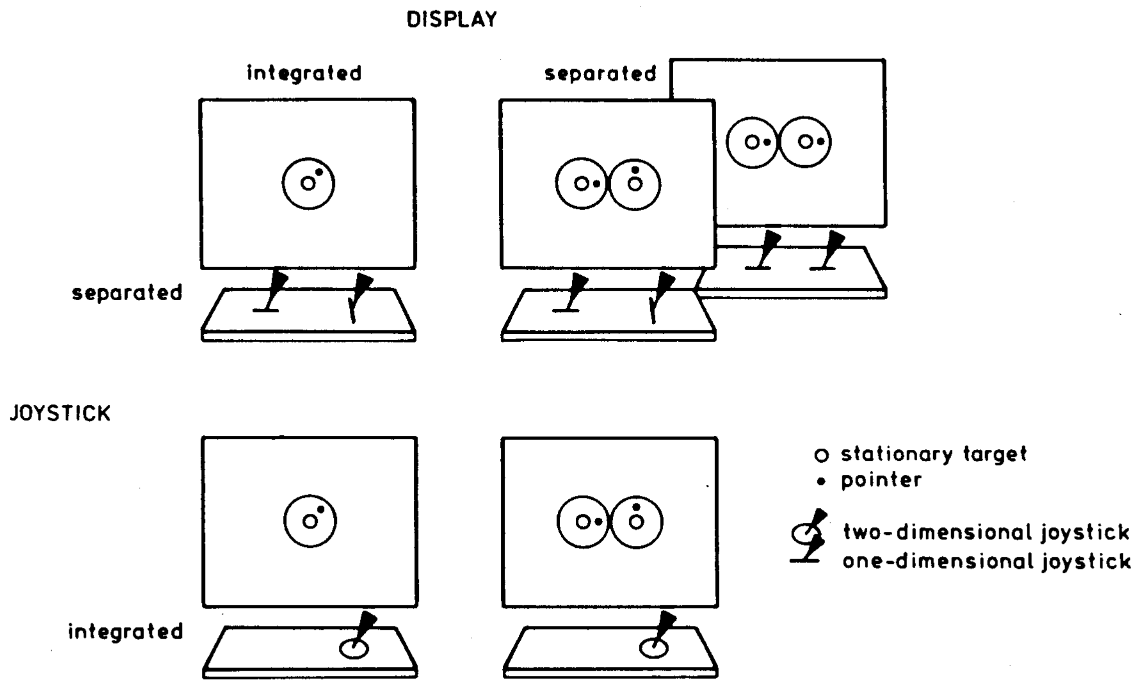

Fig. 1 Schematic representation of the stimulus-response configuration in the five experimental conditions.

2.3 Procedure

The experiment was carried out in 13 days. Two subjects participated on each day. They alternated between sessions in order to prevent fatigue effects. Subjects were seated in a dimly illuminated, sound attenuated room and were continuously monitored via a camera. The experimenter was situated in an adjacent room from where he could communicate with the subjects via an intercom.

Practice sessions

The practice sessions began with a short briefing about the general nature of the experiment. Subjects were requested to direct equal amounts of attention to both tracking tasks. In order to minimize strategic differences subjects were instructed to look between the targets. In prior studies this appeared a superior strategy, which was adopted by most subjects spontaneously.

After the general instructions the subjects practised in two single task sessions and two dual task sessions. The single task practice sessions always preceded the dual task sessions. The order of conditions within sessions, however, was balanced. A dual task practice session comprised five trials of 100 s, for every dual axis condition one trial. A single task practice session comprised four trials of 180 s each; for every single axis condition one trial. During this single task practising the amplitude gain of the forcing function was calibrated for each subject for each subtask. The criterion for the calibration procedure was a root mean squared (RMS) error 13 min arc. The amplitude gain during each single axis condition was saved and used to set the amplitude of the disturbance signal for the relevant conditions in the next dual axis session. The main aim of the individual adjustment procedure was to prevent that eventual age-related differences in dual task performance would be confounded by initial differences in tracking ability (Salthouse, 1982). This procedure also yielded subtasks of equal difficulty for all subjects.

Experimental sessions

The experimental sessions consisted of a third single task session (which was identical to the practice sessions), the paper and pencil test, and five dual task sessions.

In the single task session for every condition two measures were taken over the last 150 s of the error signal.

- Tracking performance was represented by the amplitude gain that produced the criterion-error for the calibration procedure.
- Compensatory movement speed was calculated from the power spectrum of the error signal. The power spectrum of the error signal represents the division and the weight of the frequencies of pointer movements. Since the disturbance input was low pass filtered at 1 Hz the proportion of frequencies above 1 Hz was calculated.
- After the single task session the WAIS subtest Digit Symbol Substitution was administered.

Next the five dual task sessions were carried out in balanced order, each representing one of the five experimental conditions. A session comprised five trials of 100 s with a short rest period between them.

Based on the error signals over both axes the three dual task performance measures were calculated as follows:

- For each dual task condition root mean squared tracking error was measured over 20 s intervals for each tracking axis apart. In this manner 25 error values per axis (5 intervals x 5 trials) yielded an overall tracking performance score.
- Axis cross talk was measured by calculating every 100 s the correlation between the two error signals. In the four conditions with perpendicular tracking axes the absolute correlation (pmc) was calculated, while in the condition with (separated) tracking axes in line the normal correlation was calculated.
- The proportion of frequencies above 1 Hz of the power spectrum of the error signal was calculated for each 100 s interval. For each dual task condition dual task speed decrements were represented by the difference between this proportion for each tracking axis and their single task counterparts.

3 RESULTS

3.1 Single tasks

Single axis tracking

The amplitude gains were analyzed in a 2 (age) x 2 (axis) x 2 (hand) analysis of variance (ANOVA) with age as a between groups variable. A mean gain of 332 for the young subjects (sd: 54) and 288 for their older counterparts (sd: 69) shows a slight advantage for the young $F(1,24) = 3.3$, $p = .077$. Prior experiments (Korteling, 1989; Korteling & Burry, 1989) showed comparable effects, which can be regarded as cumulative evidence for an age effect on compensatory tracking skill. There were no main effects of hand or tracking axis. However, there was a significant interaction between hand and tracking axis. For the horizontal tracking axis the left hand outperformed the right, while for the vertical axis the right hand was superior.

Power spectra-speed

A 2 (age) x 2 (axis) x 2 (hand) ANOVA on the proportions of movement frequencies above 1 Hz did not show significant main or interaction effects. There was only a tendency ($p = 0.17$) that the young (movement frequencies > 1 Hz: 34 %, sd 8.5) made quicker movements than the older subjects (movement frequencies above 1 Hz: 29 %, sd 9.0). The same tendency with almost identical proportions was found in a prior study (Korteling & Burry, 1989), showing that the power spectrum is a reliable measure, although not very age-sensitive.

WAIS Substitution

Mean scores on de subtest Substitution of the WAIS were 63.4 (sd 10.2) for the young subjects and 47.1 (sd 9.2) for their older counterparts. Hence performance differences on the test were substantial. Corrected for age, however, these scores were not significantly different, which means that the age groups matched on this intelligence subtest.

3.2 Dual tasks

On first analyses there was no indication of significant effects of hands and tracking axes, which means that the calibration procedure for single task tracking ability had been successful. Therefore, for the rest of this section these factors were taken out of consideration.

RMS tracking error

Figure 2 shows for both age groups the dual axis errors in each of the five experimental conditions. A 2 (age) x 5 (condition) ANOVA indicated superior time-sharing capabilities for the young subjects, $F(1,24) = 6.1$, $p < .05$.

There was also a main effect of conditions $F(4,96) = 5.0$, $p < .005$, which interacted with age, $F(4,96) = 4.0$, $p < .01$. A Newman-Keuls analysis on this interaction showed that performance differences as affected by age were only significant in the three conditions with integrated displays and/or integrated controls, ($p < .01$). Thus only for the older subjects the error is seen to increase when task components were integrated. This result closely links up with the data of Fracker and Wickens (1989) with young subjects. They found minimal effects of display and control integrality in a comparable dual task with more complex tracking dynamics (velocity control).

Separate ANOVA's for both groups indicated only for the older a significant effect of conditions. A Newman Keuls analysis on this effect showed that all conditions differed significantly ($p < .01$) except the conditions with complete integrated displays and controls and the condition with tracking axes in line. For the older subjects this means that in addition to the problem of integration *per se*, a compatibility of integrality effect is seen: partial task integration is more difficult than more complete task integration. Besides, in the conditions with separated display information and separated controls only the older showed a poorer performance when tracking axes were in line.

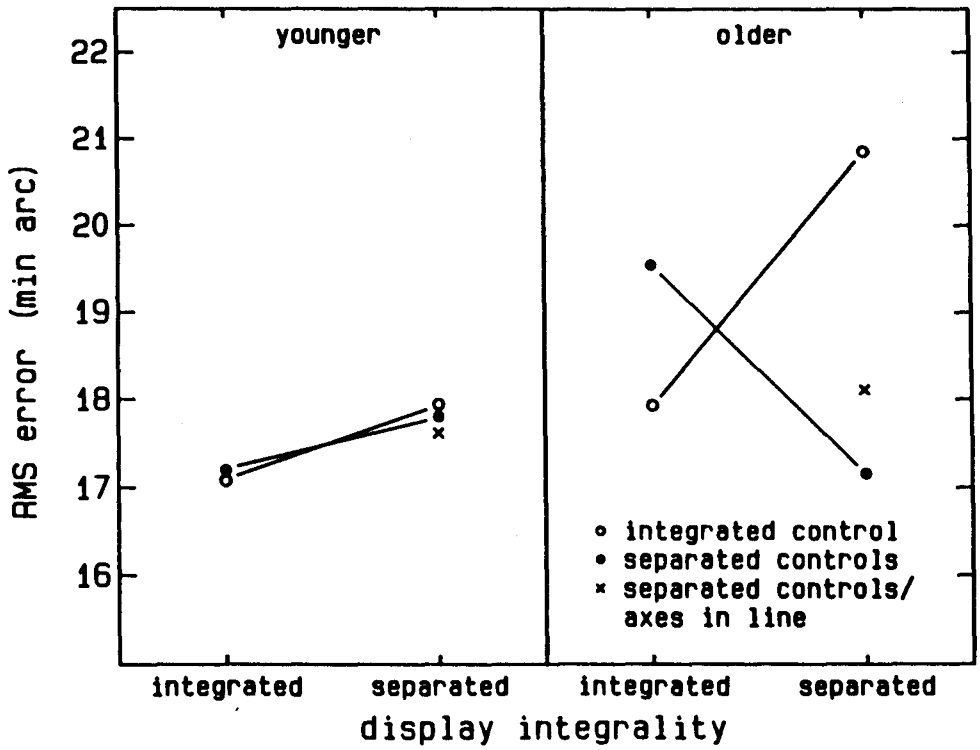

Fig. 2 Mean RMS tracking errors for the young and older subjects as affected by display integrality and control integrality. The condition with separated displays and controls is divided into a condition with perpendicular axes and one with axes in line.

Correlations between axes

In the condition with tracking axes in line correlations for the young subjects and the older were .08 (sd .032) and .13 (sd .037), respectively. These significant correlations ($p < .001$) demonstrated a cross talk effect of subtasks. Furthermore the positive sign of these correlations indicate that tracking performance was poorest when pointers were located at the same side of the targets. Also the difference between age groups was significant, $F(1,24) = 12.9$, $p < .005$. This means that with similar subtasks the older subjects were more susceptible to this cross talk than their younger counterparts.

A 2 (age) x (display integrality) x 2 (control integrality) ANOVA on the absolute correlations in the other four (perpendicular axis) conditions demonstrated a main effect of age, F(1,24) = 10.3, p < .01. Mean absolute correlations for the older (.11) were higher than for the young subjects (.08). There were no significant interactions with age. A main effect of display integrality demonstrated that for the subject group as a whole separation of the tracking axes on the display made subjects more susceptible for cross axial effects, F(1,24) = 14.1, p <.005. Fig 3 shows for both age groups a significant interaction between display and control integrality F(1,24) = 4.7, p < .05.. However, as opposed to the RMS data, this interaction was only partially consistent with a compatibility of integrality effect. Only when controls were integrated axis cross talk was high with separated and low with integrated display information. Hence, a compatibility of integrality effect was not seen when controls were separated.

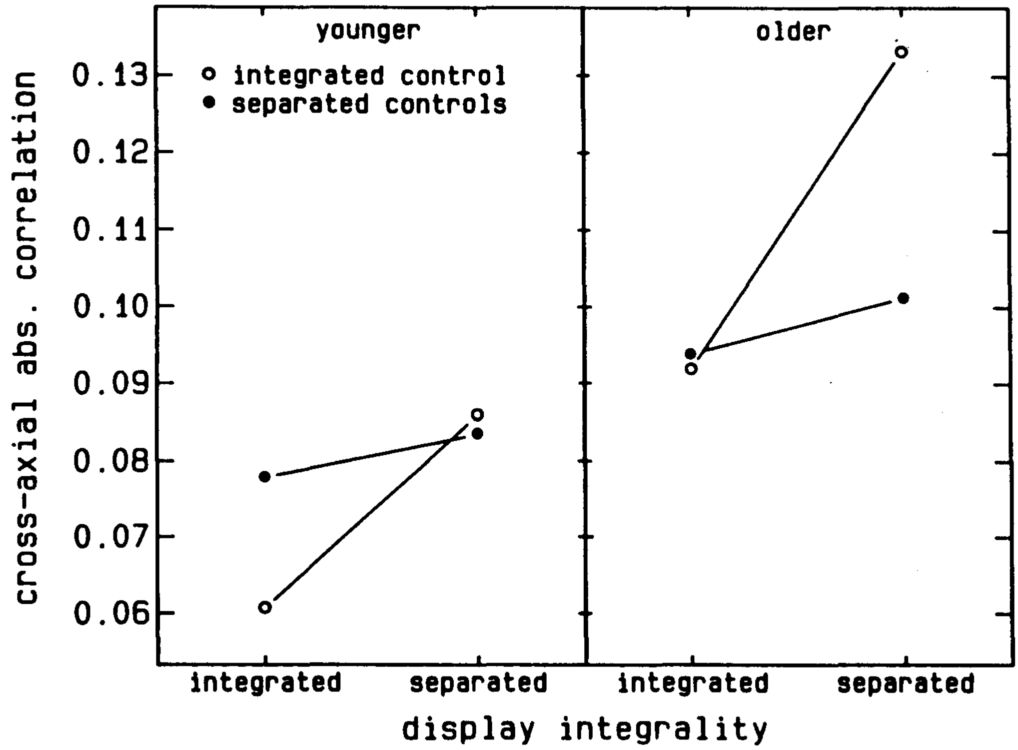

Fig. 3 Mean absolute correlations between perpendicular tracking axes for young and older subjects as affected by display integrality and control integrality.

Speed decrements

A 2 (age) x 5 (condition) ANOVA on the dual task decrements of the proportions of the power spectra above 1 Hz showed a main effect of conditions, F(1,24) = 3.48, p < .05, which interacted with age, F(4,9-6) = 3.43, p < .05. There was no main effect of age. From separate analyses it appeared that only for the older subjects the speed decrements were significantly affected by task conditions, $F(4,48) = 5.46$, $p < .005$. Hence, the elderly were seen to be more sensitive to the integrality and similarity manipulations. However, there is no consistent indication of a compatibility of integrality effect. As with the cross talk data this effect is only seen with integrated controls and not with separated controls (Fig. 4). Incompatibility of integrality seems thus to affect performance consistently when task integration is limited to the output stage. Finally, in the conditions with separated display information and separated controls only the older showed a strong speed decrement when tracking axes were in line. Together with the RMS and cross talk data concerning the effects of task similarity this substantiates the evidence for the hypothesis that performance of older people is hampered when subtasks become more similar.

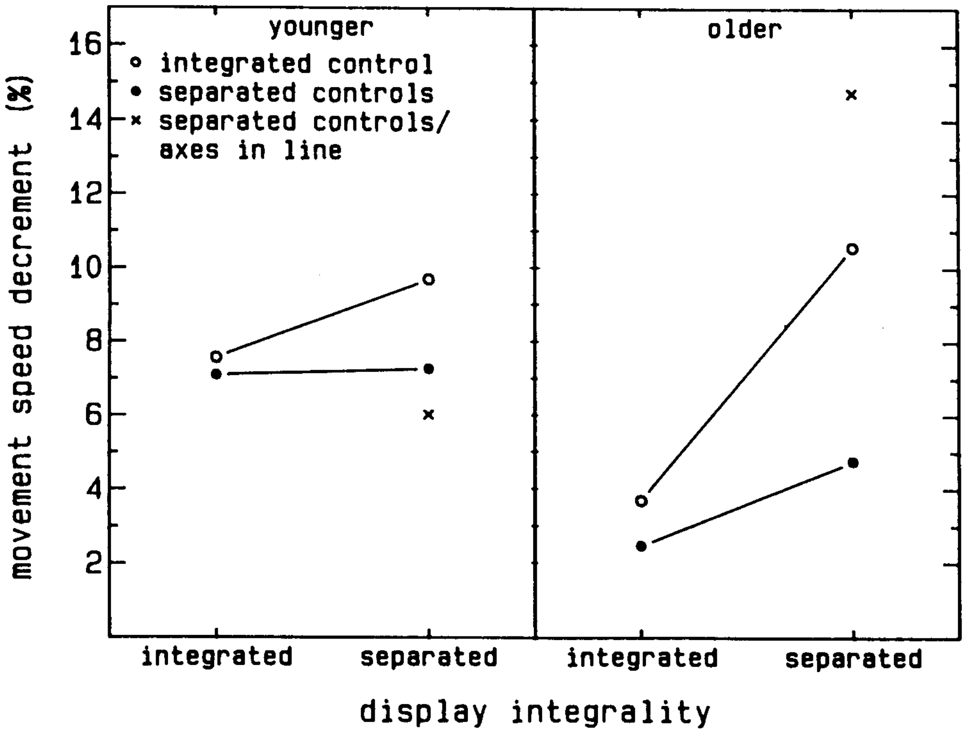

Fig. 4 Dual task decrements of the proportions of the power spectra above 1 Hz for the young and older subjects as affected by display integrality and control integrality. The condition with separated displays and controls is divided into perpendicular axes and one with axes in line.

3.3 Correlations between dependent measures

Correlations between the dependent variables may give insight in the interdependencies of skills. Table I shows for each age group the correlations between these variables (the absolute correlations were calculated over all five conditions). For the older group the single task speed measures (no. 1, 2 & 3) were correlated, which substantiates the idea that these measures all reflect information processing speed. Since interindividual differences in processing speed increase with age, the lower correlations between these measures for the young is not surprising. This indicates that only for the older subjects information processing speed was a factor of major importance in determining interindividual performance differences on these tasks.
Two of the three speed measures were significantly associated with cross axial absolute correlations (no. 5). This demonstrates that for both age groups axis cross talk decreased with increasing information processing speed. This replicates the results of an earlier experiment (Korteling & Burry, 1989) in which the cross talk between tracking axes was found to be correlated with comparable speed measures.

Table I Correlations between means of 6 dependent variables (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$)

OLD SUBJECTS	1	2	3	4	5
1. Single Axis Amplitude Gain					
2. % > 1 Hz Power spectrum Single	.97***				
3. Digit Symbol Substitution	.59*	.56*			
4. Dual Task RMS	.46	.39	-.30		
5. Absolute correlation	-.89***	-.85***	-.18	-.38	
6. Dual Task Speed Decrement	.44	.44	-.29	.61*	-.33

YOUNG SUBJECTS	1	2	3	4	5
1. Single Axis Amplitude Gain					
2. % > 1 Hz Power spectrum Single	.88***				
3. Digit Symbol Substitution	.19	-.14			
4. Dual Task RMS	.36	.68*	.29		
5. Absolute Correlation	-.58*	-.63*	-.23	-.49	
6. Dual Task Speed Decrement	-.24	.00	-.59*	-.07	.43

For both groups the other specific dual task measures (no. 4 & 5) were hardly associated with the speed measures (no. 1, 2 & 3). This strong-

ly suggests that specific dual task skills were not substantially associated with information processing speed. For the relation between these dual task measures and axis cross talk the same conclusion can be drawn.
For the older a significant correlation was found between both general tracking performance and speed decrement (no. 4 & 6). This means that dual task performance was significantly associated with a measure for remaining effective dual task resources. In other words: older subjects whose resources came under increasing demand also showed a poor dual task performance. Other relations between dual task measures were not found. In the light of the consistent effects documented in the preceding section this means that the effect of subject-skills on dual task measures is not as consistent as the effect of task conditions on dual task measures.

4 DISCUSSION

The aim of the present experiment was to investigate age-effects in pure dual task performance (RMS tracking error, axis cross talk, and movement speed decrement), as affected by the manner in which subtasks are integrated. It was expected that age effects in dual task performance will increase when tasks are partially integrated such that extra, or more precise, mapping operations between display information and control actions are required. Also relations between performance measures and indices of information processing speed were taken into consideration.
It was found that RMS performance differences between the older and the young substantially increased when compatibility of integrality was low, i.e. when display integrality was not matched with control integrality. Age-related differences were small, but also significant, when display information as well as the control was integrated. Age effects were not significant when the subtasks were completely separated. Furthermore, only the older subjects' performance was hampered by increasing similarity of separated subtasks. The finding that the young subjects outperformed the older only when the compatibility of integrality was low or when subtasks were similar (tracking axes in line instead of perpendicular) strongly supports the idea that older people may be extra penalized when dual tasks are integrated such that extra, or more precise, mapping operations between stimuli and actions are required.

With reference to the ability to keep subtasks separate it appeared that cross axial correlations were maximal when integrated controls were combined with separated display information and minimal when display information was also integrated. This compatibility of integrality effect was not found in the conditions with separated controls. In case of similar subtasks especially the older subjects tended to keep both pointers at the same side of the targets. When both pointers are located at the same side of the targets the subtasks may be regarded maximally similar. Therefore this may also point at the conclusion that the older subjects' performance is more hampered than that of their younger counterparts when the subtasks become more similar.

In accordance with the cross talk data the dual axis speed decrements only produced an age-related compatibility of integrality effect in the conditions with integrated controls. Hence, the data were only in support of the hypothesis that mapping requirements in the integrated conditions were extra resource demanding for the older, when controls were integrated. With respect to this hypothesis a significant correlation was found between RMS tracking scores and dual task speed decrements of the older subjects. This may indicate that there is a relation between effective resources and dual task performance. In specific: older subjects whose resources came under increasing demand also showed a poor dual task performance.

With respect to the effect of subtask similarity it was found that movement speed of the older subjects decreased substantially with separated subtasks in line. So, as opposed to the young subjects, the older subjects effective resources were reduced when subtasks became more similar. With this conclusion all performance measures (RMS, axis cross talk, and movement speed) demonstrated that performance of older people is degraded when subtasks become more similar.

Cross talk was significantly correlated with speed measures. Processing speed, however, was not found to be correlated with indices reflecting other pure dual task skills. These findings replicate the data of Korteling & Burry (1989). This suggests that information processing speed has something to do with the capacity to keep simultaneous information processes and action processes separate. It may therefore be presumed that neuronal degenerative processes with age (e.g. Brody & Vijayashankar, 1977) decrease the speed of mental operations and increase the mutual interference of simultaneous operations. More data will be needed to know ***how*** this occurs.

In summary, the present study demonstrated that older people may have extra difficulties when dual tasks are only partially integrated such that this integration requires the performance of extra mapping operations between stimulus and response. When the integration was limited to the response part of the task this effect was seen over all three dependent dual task variables. With respect to the cross talk and speed decrement data partial integration on the level of subtask stimuli did not produce a disproportional negative effect on the older subjects' performance. Also with respect to the requirement of making more ***precise*** mapping operations, caused by increased subtask similarity, there was a strong negative effect of age. Together with the higher cross axial correlations of the older this finding may indicate that with increasing age it becomes more difficult to keep simultaneous processing operations (e.g. in attention, perception, information processing, and action) separate. Furthermore, there appears to be a (causal) relationship between this skill and age-related slowing. At this point the results are fully in accordance with the slowing-complexity hypothesis, stating that by general slowing age effects are proportional to task complexity (mapping demands). However, this hypothesis seems not to be a satisfactory explanation for the increasing age effects on dual task performance for slower subjects. In replication of an earlier experiment (Korteling & Burry, 1989), correlations between three measures for processing speed and two measures for dual task performance were sparse.

What may the above findings imply with respect to the capabilities of older traffic participants? First, in the area of automobile ergonomics, integration may not always be an optimal solution to cope with the increasing complexity of modern traffic. This may especially count for control devices. Therefore controls should not have too many functions, e.g. wiper, light and claxon should not be mounted on one control stalk. Furthermore similarity in design and function of different control and monitoring devices should be avoided. The present development of multi-purpose electronic displays for the presentation of information from different sources may especially for older people offer new problems when too much information is simultaneously presented at the same place.

In real traffic a particular situation often contains many stimuli triggering incompatible actions. For example when approaching an intersection a car driver should give right of way to motor vehicles coming from the right side. However, this does not count when bicyclists or pedestrians cross the road from right. Also, traffic lights or major road signs may overrule these rules. This kind of complexities may be one of the main factors determining problems of older subjects with giving way to other traffic (Korteling, 1988). This, in turn, may be caused by the complex mapping of simultaneous stimuli to responses in ordinary traffic. Although these complexities probably can never be ruled out completely, it would be recommendable to keep traffic situations as simple as possible. In order to attain this aim comparable traffic situations should be designed as uniformly as possible. Besides roads should be "self-explaining". This means that traffic behaviour should be controlled by the (structural) properties of the situation with an intrinsic connection to desired behaviour rather than by additional means which lack such an intrinsic link between the situation and desired behaviour.

REFERENCES

Boer, L.C. (1984). Attention tasks and their relation to aging and flight experience. Report IZF 1986-4, TNO Institute for Perception, Soesterberg.

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

Brody, H. and Vijayashankar, N. (1977). Cell loss with aging. In K. Nandy and I. Sherwin (Eds). The Aging Brain and Senile Dementia, Advances in Behavioral Biology. Vol 23. New York: Plenum Press.

Cerella, J., Poon, L. and Williams, D. (1980). Age and the complexity hypothesis. In: L. Poon (Ed.) Aging in the 1980s. Washington DC, American Psychological Association, 332-340

Clark, L.E. and 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.

Fracker, M.L. and 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.

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

Korteling, J.E. (1988). Information processing of older traffic participants. Report IZF 1988-9, TNO Institute for Perception, Soesterberg.

Korteling, J.E. (1989). Skill integration and perceptual competition: Factors affecting age-related differences in dual task performance. Report IZF 1989 C-1, TNO Institute for Perception, Soesterberg.

Korteling, J.E. and Burry, S. (1989). Effects of age and repeated practice on dual task performance. Report IZF 1989-34, TNO Institute for Perception, Soesterberg.

Luteyn, F. (1976). A method for estimating premorbid intelligence, Dutch Journal of Psychology 26, 60-69.

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

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

Navon, D. and Gopher, D. (1979). On the economy of the human processing system. Psychological Review 86, 214-225.

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

Neumann, O. (1987). Beyond capacity. In H. Heuer & A.F. Sanders (Eds). Tutorials on perception and action. Hillsdale, N.J.: Lawrence Erlbaum, 361-394.

Pew, R.W. (1969). The speed-accuracy operating characteristic. Acta Psychologica 30, W.G. Koster, (Ed) Attention and Performance II, North-Holland Publishing Company, Amsterdam, 16-26.

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

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

Sanders, A.F. (1963). The selective processes in the functional visual field. Van Gorcum, Assen, The Netherlands.

Sanders, A.F. and Houtmans, M.J.M. (1984). The functional visual field revisited. In A.J. van Doorn, W.A. van de Grind and J.J. Koenderink (Eds). Limits in perception (pp 359-380). Utrecht VNU Science Press.

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

Wickens, C.D. (1984). Processing resources in attention. In R. Parasuraman and D.R. Davies (Eds) Varieties of Attention (pp 63-102). New York: Academic Press.

Wright, R.E. (1981). Aging, divided attention and processing capacity. Journal of Gerontology 36, 605-614.

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14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

An earlier experiment showed that in a dual task older adults do not benefit from stimulus synchronization as much as younger subjects do. Only young subjects were able to combine skills for separate subtasks into more integral dual task skills. This integration of skills is only possible when subtasks are connected or related ("task integration"). However, task integration may also hamper task performance. This is supposed to be the case when the compatibility between stimulus and response decreases or when subtasks become too similar to keep them sufficiently separate (e.g. combining different functions at one control stick). If older people have difficulties with this, task integration may impede their task performance. In the present experiment this issue was addressed with a dual task consisting of two one-dimensional compensatory tracking tasks with perpendicular tracking axes. Based on independent manipulations of display and joystick integrality the dual task was carried out under four conditions of compatibility. One condition was also carried out with tracking axes in line. This increasing task similarity of subtasks was supposed to make it more difficult to keep the subtasks separate, causing interference or "cross talk" in task performance. Data reflecting general tracking performance were consistent with the hypothesis that older subjects are extra penalized when task integration decreased the degree of compatibility of integrality. The cross talk data were only consistent with the compatibility of integrality hypothesis in the conditions with an integrated joystick. The idea that incompatibility of integrality should consume extra resources (decreasing movement speed), also was only supported in the conditions with an integrated joystick. All performance measures (tracking performance, axis cross talk, and movement speed) supported the hypothesis that with increasing subtask similarity performance of older people is degraded. Cross talk was significantly correlated with processing speed. Processing speed, however, was not found to be correlated with indices reflecting other pure dual task skills (general tracking performance and movement speed decrement). Theoretical and practical implications of these findings are discussed.

16. DESCRIPTORS	IDENTIFIERS
Age	Age
Ergonomics	Task Integration
Perceptual Motor Skills	Dual Task Performance
Task Complexity	Processing Speed
Tracking	Compensatory Tracking
Vehicle Driving	
Visual Displays	

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