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J.E. Korteling
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PARTIAL CAMERA AUTOMATION IN A SIMULATED UNMANNED AIR VEHICLE

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The data showed that subjects performed substantially better with an active system. Apparently, the subjects had no difficulty in maintaining control; i.e., "following" the active stick while superimposing self-initiated control movements over the system-interventions. Furthermore, tracking performance with an update frequency of 5 Hz was clearly superior relative to 2 Hz. The magnitude of the active-interface effect was equal to the update-frequency effect. On the basis of effects of difficulty in steering dynamics, it was also concluded that the benefits of update frequency enhancement and semi-automated tracking will be the greatest under difficult tracking conditions. Mental workload scores indicated that for the difficult tracking-dynamics condition, both semi-automation and frequency increase resulted in less experienced mental effort in task performance. For the easier dynamics this effect was only seen for update frequency.

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De snelle ontwikkelingen binnen de automatisering en robotica hebben laten zien dat veel menselijk werk door machines kan worden verricht. Echter, sommige menselijke activiteiten kunnen goed worden geautomatiseerd an anderen niet. Bovendien is de mate van automatisering van doorslaggevend belang voor de flexibiliteit en mogelijkheden van een systeem waarin de vaardigheden van de operator maximaal moeten worden benut. Daarom is het een belangrijke vraag hoe de verdeling van arbeid tussen mens en automaat moet worden geregeld, gegeven de huidige staat van de technologie en de menselijke mogelijkheden. De onderhavige studie betrof in dit verband een intelligente, semi-autonome, interface voor een camera operator in een gesimuleerd onbemand vliegtuig (Unmanned Air Vehicle, UAV). Deze interface gebruikte inherente "systeemkennis" met betrekking tot beweging van het UAV om een camera operator te helpen bij het volgen van een bewegend object door het landschap. Dit landschap werd geregistreerd door de videocamera aan het UAV-platform en voor de operator gepresenteerd op een monitor. Het semi-geautomatiseerde systeem compenseerde hierbij voor de translaties van het UAV ten opzichte van de aarde. Deze compensatie ging gepaard met de bijbehorende joystick bewegingen (om deze camera-rotaties te bewerkstelligen) zodat tevens tactiele (haptische) informatie over deze systeem interventies werd gegeven. De camerabestuurder moest, over de door het systeem geïnitieerde camera acties, zelf camerabewegingen bewerkstelligen die nodig waren om het bewegende doel te volgen. De operator bleef dus 'in the loop'; hij had volledige controle over het camera systeem. Om het effect van semi-automatisering over een bredere range van taakcondities te onderzoeken werd de stuurtaak uitgevoerd onder twee condities van update frequentie van het buitenbeeld en stuurdynamica.

Uit de resultaten bleek dat de proefpersonen met het actieve systeem beduidend beter presteerden. Blijkbaar hadden zij geen moeite het actieve systeem te beheersen, i.e., met het volgen van de actieve stick en het tegelijkertijd hierover superponeren van de eigen stuurbewegingen over de systeem interventies. De prestatie werd eveneens aanzienlijk verbeterd door de update frequentie van 2 Hz te verhogen tot 5 Hz. De grootte van deze effecten was nagenoeg gelijk. Omdat er geen interactie tussen beide interface variabelen optrad mogen de positieve effecten van de actieve interface en hogere update frequentie als additief worden opgevat. Geconcludeerd werd daarom dat de huidige actieve interface op eenvoudige wijze een extra systeemverbetering bewerkstelligt. Op basis van de effecten van stuurdynamica werd geconcludeerd dat de voordelen van de gebruikte semi-automatisering en verhoogde update frequentie het grootst zijn onder moeilijke stuurcondities. Scores op een vragenlijst voor mentale werklast lieten zien dat voor de moeilijke tracking-dynamica conditie zowel de hogere graad van automatisering als van update frequentie een geringere ervaren mentale inspanning tot gevolg had. Voor de makkelijke dynamica conditie bleek dit alleen voor update frequentie het geval. Vervolgonderzoek zal worden gericht op de noodzaak van haptische feedback via de joystick en de signaalkarakteristieken daarvan.

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CONTENTS

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SUMMARY

With the rapid development of automatic control techniques a central question is how the division of labor between the human operator and the automaton should be optimally distributed. In this connection, the present study focussed on an intelligent, semi-autonomous, interface for a camera operator of a simulated Unmanned Air Vehicle (UAV). This interface used inherent system "knowledge" concerning UAV motion in order to assist a camera operator in tracking an object moving through the landscape below. This landscape was sensored by the video camera attached to the UAV-platform and presented to the operator on a monitor display. The semi-automated system compensated for the translations of the UAV relative to the earth. This compensation was accompanied by the appropriate joystick movements ensuring tactile (haptic) feedback of these system interventions. The operator had to superimpose camera movements over these system actions required to track the motion of a target (a driving truck) relative to the terrain. Consequently, the operator remained in the loop; he still had total control of the camera-motion system. In order to investigate the effects of this semi-automation over a broad range of task situations, the tracking task was carried out under two conditions of update frequency of the monitor image and control mode difficulty.

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Soesterberg

Gedeeltelijke camera-automatisering in een gesimuleerd onbemand vliegtuig

J.E. Korteling en W. van der Borg

SAMENVATTING

Met de snelle ontwikkelingen binnen de automatisering en robotica is het een belangrijke vraag hoe de verdeling van arbeid tussen mens en automaat moet worden geregeld. De onderhavige studie betrof in dit verband een intelligente, semi-autonome, interface voor een camera operator in een gesimuleerd onbemand vliegtuig (Unmanned Air Vehicle, UAV). Deze interface gebruikte inherente "systeemkennis" met betrekking tot beweging van het UAV om een camera operator te helpen bij het volgen van een bewegend object door het landschap. Dit landschap werd geregistreerd door de videocamera aan het UAV-platform en voor de operator gepresenteerd op een monitor. Het semi-geautomatiseerde systeem compenseerde hierbij voor de translaties van het UAV ten opzichte van de aarde. Deze compensatie ging gepaard met de bijbehorende joystick bewegingen (om deze camera-rotaties te bewerkstelligen) zodat tevens tactiele (haptische) informatie over deze systeem interventies werd gegeven. De camerabestuurder moest, over de door het systeem geïnitieerde camera acties, zelf camerabewegingen bewerkstelligen die nodig waren om het bewegende doel te volgen. De operator bleef dus "in the loop"; hij had volledige controle over het camera systeem. Om het effect van semi-automatisering over een bredere range van taakcondities te onderzoeken werd de stuurtaak uitgevoerd onder twee condities van update frequentie van het buitenbeeld en stuurdynamica.
Uit de resultaten bleek dat de proefpersonen met het actieve systeem beduidend beter presteerden. Blijkbaar hadden zij geen moeite met het volgen van de actieve stick en het tegelijkertijd hierover superponeren van de eigen stuurbewegingen over de systeem interventies. De prestatie werd eveneens aanzienlijk verbeterd door de update frequentie van 2 Hz te verhogen tot 5 Hz. De grootte van deze effecten was nagenoeg gelijk. Op basis van de effecten van stuurdynamica werd geconcludeerd dat de voordelen van de gebruikte semi-automatisering en verhoogde update frequentie het grootst zijn onder moeilijke stuurcondities. Scores op een vragenlijst voor mentale werklast lieten zien dat voor de moeilijke tracking-dynamica conditie zowel de hogere graad van automatisering als van update frequentie een geringere ervaren mentale inspanning tot gevolg had. Voor de makkelijke dynamica conditie bleek dit alleen voor update frequentie het geval.

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1 INTRODUCTION

Aircraft missions have developed to the point where small, flexible and safe systems can elaborate the existing capabilities for data registration and communication. One major outcome of this development is *unmanned-air-vehicle* (UAV) technology. UAVs are small air vehicles designed to carry out various (dangerous) missions without a human operator aboard. The vehicle typically is controlled by human operators at a remote location. This crew performs a number of basic functions which are common to most UAV missions, i.e.: mission planning, navigation and platform control, payload (sensor) control, data analysis, launching and recovery, and communication. Depending of the kind of missions and systems these functions can be divided over one or several operators. In most existing systems these functions are carried out by at least three operators (Denaro, Kalafus & Ciganer, 1989).

Imaging devices are likely the most common form of UAV payload (Eisen & Passenier, 1991). A camera-monitor system can serve two general purposes, i.e., vehicle guidance and information acquisition. During the operation of an imaging sensor, it is usual that at least one operator is engaged in visual search and detection, normally followed by recognition and identification. In these kinds of operations (e.g., scouting, battle-damage assessment) control of imaging system is one of the most critical conditions for success. The platform operator performs a support function by adapting the flight profile to the mission plan, to potential threats and to the limitations of the platform and its sensor system. The present study was undertaken to determine the effects of two interface factors on sensor control performance of a operator who tracked a moving visual target from a flying simulated UAV.

For many (military) UAV missions the update frequency of the visual image generated by the camera-monitor system is low due to the requirement to digitize and code the image-signal. An update frequency of 1-4 Hz is realistic and a maximum of 5-6 Hz may be attained by 1996 (Van Breda & Passenier, 1993). This low frequency may degrade the perception of object and egomotion (Wagenaar, Frankenhuizen, Vos & Flores d'Arcais, 1984). Van Breda and Passenier (1993), for example, who investigated steering performance in a simulated UAV task, found severe performance decrements when the update frequency of the image decreased below 4 Hz. They recommended to select update frequencies above 10 Hz.. Since this level is often not feasible, other solutions may help to overcome tracking decrease by update limitations.

The present study focussed on an intelligent, semi-autonomous, interface as a possible solution to this problem. The rapid development of automatic control techniques in the past decades has shown in how many aspects of human work humans can be replaced by machines. However, some human activities can easily be automated and others not. The degree of automatization of a control mechanism represents a trade-off between the range of capabilities and the degree of flexibility of a man-machine system in which the potential capacities of the operator have to be maximally utilized.

At one hand, total automatization implies that the entire mission is *a priori* planned and programmed. The pilot is relieved from all low-level ("inner loop") functions to such a degree that he even may be able to supervise (high-level or outer loop control) a number of UAVs (e.g., Womack & Steczkowsky, 1988). However, automatic guidance, for example by keying in waypoints, does not lend itself to real-time adaptations to the requirements of unexpected situations, requiring quick and specific actions or interventions, e.g., pursuit tracking a moving vehicle. This can only be accomplished by spatial input devices, such as joysticks.

At the other end of the automation range, complete human manual control requires a ground station that is outfitted with very similar controls to those found on board of an aircraft. In addition, the pilot would need extensive flight training (instrument rated) and, due to a lack of visual an mechanical (haptic, vestibular) motion information, additional information should be provided on the console. In these cases, the span of subtasks (ranging from low-level vehicle control to advanced data processing techniques) will be limited or training requirements and human-machine interface requirements may lead to cost-ineffective operation. In addition, total task performance may depend on too many different operators, all having access to only a limited set of the data; the data related to the individual, circumscribed sub-tasks, the sum of which making up the whole integral task. Consequently, too much time-consuming communication will be required in order to reach optimal action. In general, improvements in regulation in the inner loops provide an increasing range of freedom in the outer loops of a control hierarchy (Kelley, 1968). On balance, given the status quo of the technical possibilities in each design process of complex man-machine systems, a central question is how the division of labor between the human operator and the automaton should be optimally distributed.

In some circumstances the ratio of control range *vs* control flexibility may be increased by means of intelligent routines automatizing or linking subtasks and/or incorporating potential available data about the system in its task environment. In a previous study, conducted at the TNO Human Factors Research Institute, this approach has been successfully demonstrated. In this study imaging-payload and UAV control were coupled such that one operator, who controlled and monitored both the platform and the imaging sensor at the same time, directly steered the sensor footprint, rather than acting indirectly upon it via separate sensor and vehicle commands. Computing intelligence must then allocate the requested footprint motions to UAV and payload commands. This solution, which proved to make lower demand upon the operator while enhancing tracking performance, has the potential drawback of reducing the possibilities of scanning around a target of interest. That is, flight path around the target and viewing direction were to a certain degree dependent.

In the present study, another kind of semi-automation was tested which was based on routines processing inertial information concerning UAV motion that actively assisted a camera operator in tracking a moving object with a joystick. In this study the system compensated for the translations of the UAV relative to the earth. This was accompanied by the appropriate joystick movements ensuring tactile (haptic, proprioceptive) feedback of these system interventions. Hence, the active system could be regarded as involving an "intelligent" stick that helped the operator by moving autonomously and thereby compensating for the translations (not the rotations) of the UAV relative to the present "footprint" of the camera on the terrain. A potential drawback of these kinds of continuous assistance is that it may disturb the operator's "internal model" of the regular system dynamics (Kelley, 1968). For the present study, it was supposed that such negative "transfer" effects would be rather small compared to the potential beneficial effects of the assistance in tracking. In addition, experimental results suggest that continuous support in driving tasks may be beneficial (Godthelp, 1990; Schumann, Godthelp & Hoekstra, 1992) and potentially even more beneficial than discrete (warning) signals with a much lower information value (Schumann, 1994). Rotations of the UAV were, as is usual, compensated by gyroscopic precession. The operator had to superimpose camera movements over these system actions required to track the motion of the target relative to the earth. Consequently, the operator remained in the loop; he still had total control of the camera-motion system. In order to investigate the effects of this semi-automation over a broad range of task situations, the tracking task was carried out under two conditions of update frequency and control mode difficulty.

2 METHOD

2.1 Subjects

The experiment was conducted with two groups of 8 right-handed subjects between 25 and 35 years of age. These subjects were paid for their participation. They had normal or corrected-to-normal vision and were no eager players of computer games (< 1 hour/week). Subjects were matched on educational level.

2.2 Experimental task

Subjects were seated at a distance of 130 cm before a 19-inch monitor. This monitor showed a motor-truck (driving speed 60 km/h) following one of several predetermined routes consisting of curves and straight stretches. The landscape consisted of a flat terrain mainly containing gras and moorland (Fig. 1). Curves were left and right and varied between 90 - 360 degrees. The image was simulated as sensored by a TV-camera located under an UAV flying over the landscape. This UAV also moved autonomously according to a predetermined route.

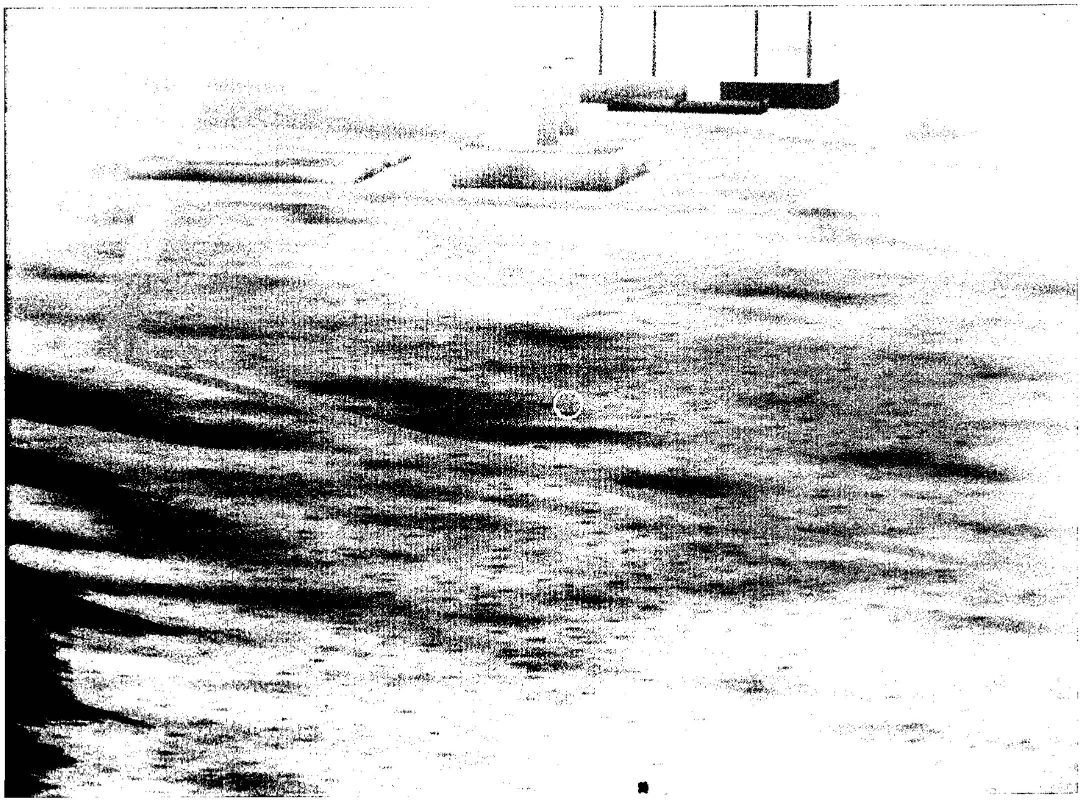

Fig. 1 The simulated landscape including the center circle and the driving truck (middle-below).

Subjects were instructed to keep the truck as well as possible in the center (marked by a circle, the tracking symbol, 0.8°) of the monitor image. This had to be done with a joystick. In curves the camera maintained its viewing direction relative to the earth. This spatial constancy is based on the same principle, as a conventional attitude indicator in airplanes, i.e., gyroscopic precession. Practically, this meant that the system automatically compensated for UAV rotations. This means that the subjects had to compensate for UAV translations and for truck motions (translations and rotations).

Task dynamics

The routes of the truck and the UAV were chosen such that the distance between them was always between 4 and 6 km. The mathematical model for calculation of flight behavior of the UAV and driving behavior of the target vehicle was based on a fixed altitude for both. The UAV had an altitude of 600 m above the terrain level where the truck was driving. During forward translations the driving speed of the target was 60 km/h and the ground speed of the UAV 120 km/h. Turning rates of the target were variable around 5°/s with one or two peaking to 10°/s. For the UAV this was exactly the opposite, i.e., primary 10°/s with one or two slower curves of about 5°/s. Each scenario (trial) contained 9-10 reversals, both for the UAV as well as for the target. In pilot studies, the difficulty of the scenarios were leveled. Camera direction could be varied 360° in the horizontal direction and downward from 4-60°.

Field of view

Object identification is the most critical task component of the camera operator and if an operator is able to perform the tracking task under identification conditions, he certainly may be expected to perform the task well under less critical conditions, i.e., target detection or recognition. Since it is crucial for the identification-phase to see the object of interest with a maximal level of detail ánd to keep it continuously on the screen, a special zoom-routine kept the field of view (FOV) as small as possible. When the moved away from the center of the image such that it crossed an imaginary circle around the center of the monitor screen, this routine made the (FOV) to expanded automatically, which could be accomplished until a maximal magnification factor of 30. During pilot experiments this appeared for all subjects enough to keep the target within the FOV of the camera. During the experimental trials, however, two occasions arose in which a subject lost the target (both in the most difficult conditions involving passive, low-update position control). Expansion of the FOV was zero when the tracking symbol was within the range of 0.33° from the target (circle-diagonal = (minimal vertical FOV)/2). This was regarded as a criterion for perfect task performance, which also was taken into consideration in the data analyses.

2.3 Independent variables

In the experiment three factors were varied, two within subjects (interface and update frequency) and one between subjects (steering difficulty).

Interface type

The camera control system could be active or passive. In the active conditions the system generated camera movements compensating for the UAV-translations. Feedback with reference to these system actions was given by the joystick that moved according to these autonomous camera movements. These compensatory actions can be calculated by an algorithm based on the momentary camera direction, and the known flying direction, speed and viewing distance of the UAV. In operational UAV missions, direction and speed are known by gyroscopic precession and the viewing distance (or altitude) can be programmed by the operator.

Update frequency

On the basis of practical significance with regard to update frequencies of real UAV systems the update frequency of the monitor image was chosen to be 2 or

5 Hz. For military systems 2 Hz lies centrally within the limits of most present systems (1-4 Hz) and 5 Hz is expected to be possible in the near future (Vitro, 1994).

Steering difficulty

Steering difficulty was manipulated by varying the control dynamics, i.e., the relation between a joystick movement and the resulting camera motion. Because this kind of system dynamics variation will generate significant (negative) transfer between succeeding conditions (Poulton, 1974), this independent variable was manipulated as a between-subjects variable. Velocity control and position control were chosen to represent the easy [usual for the present kind of systems) and difficult (unusual)] conditions, respectively. In the present experiment, position control was difficult because rotations of the camera will change the relationship between the error as seen on the display and the required direction of joystick manipulations. For example, a backward orientation of the camera resulted in a reversal of the relationship between joystick an camera motions. With position control, there is basically a direct relationship between a control movement and a display movement. However, because the UAV on which the camera was mounted was also moving, this relationship gradually changed during a trial. Therefore, the subject had to take into account his own changing spatial position relative to the target. With velocity control, a control movement gives the camera a turning rate in the direction of the control movement. This rate increases with the displacement of the control. When the marker on the camera has reached the target the velocity has to be nulled by moving the control back to its center. Hence, contrary to position control, the relation between joystick and camera motions remain the same.

2.4 Dependent variables

In order to measure tracking performance with the simulated camera-monitor system Root Mean Squared (RMS) errors were measured for each trial in each experimental condition. Error was defined as the deviation of the center of the tracking symbol on the monitor screen from the center of the target in degrees of angle. This deviation was sampled by 1 Hz.

In addition, subjective workload was measured with a Dutch scale for Mental Effort Assessment, termed BSMI[2] (Zijlstra, 1993). Following each trial this list was presented on a second monitor and subjects were requested to select a value on this list. This BSMI, developed by Zijlstra and Van Doorn (1985), registers mental effort as experienced by the operator. This method has been applied in laboratory and in practical situations as well has been shown to discriminate between tasks that vary in difficulty (Zijlstra & Meijman, 1988). Moreover, various investigators conclude that for general mental effort assessment simple

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[2] BSMI: Beoordelingsschaal Mentale Inspanning

scales, such as the BSMI, appear has valid, or even better, than the extensively validated—but long and complex—Task Load Index (Hendy, Hamilton & Landry, 1993; Veltman & Gaillard, 1993).

2.5 Instrumentation

The experiment was carried out on the TNO-TM simulator, consisting of an image generation and projection system for presentation of the outside view, an instrumented console with display and controls, and computer systems for calculation of the dynamic behavior of the UAV and camera system and for data storage. Image generation and projection were produced by an Evans & Sutherland ESIG-2000 graphic image generator interfaced to a Silicon Graphics 19-inch monitor, producing a an 800 × 600 pix resolution with including texturing. Each image could contain 1500-200 polygons (30 Hz). The viewing angle varied between 52 × 40° for zoom factor 1 and 1.7 × 1.3° for zoom factor 30. Required steering inputs remained within 15% of the dynamic limits of the steering system (300°/s).

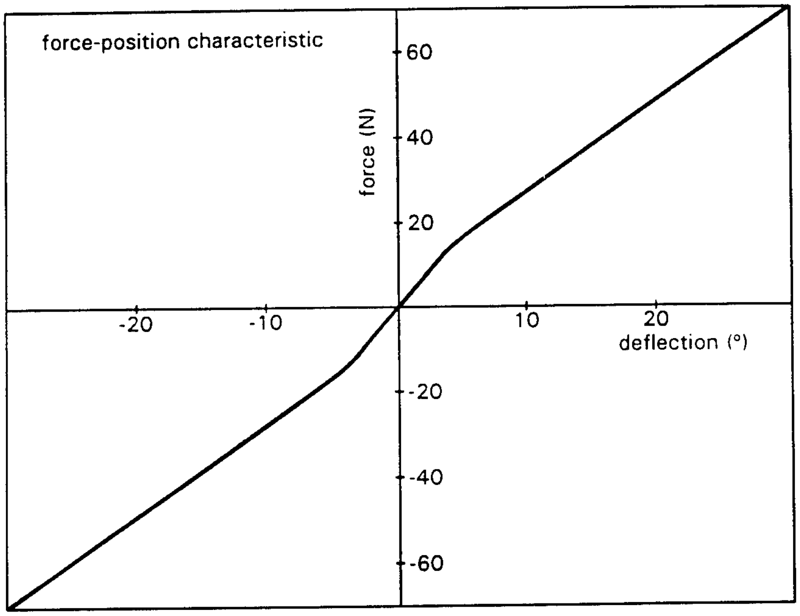

Fig. 2 The relation between joystick force and position.

In the experiment various parallel computer systems were used for:

- calculation of the dynamic behavior of the UAV and the target vehicle (30 Hz);
- scenario-generation
- raw data storage.

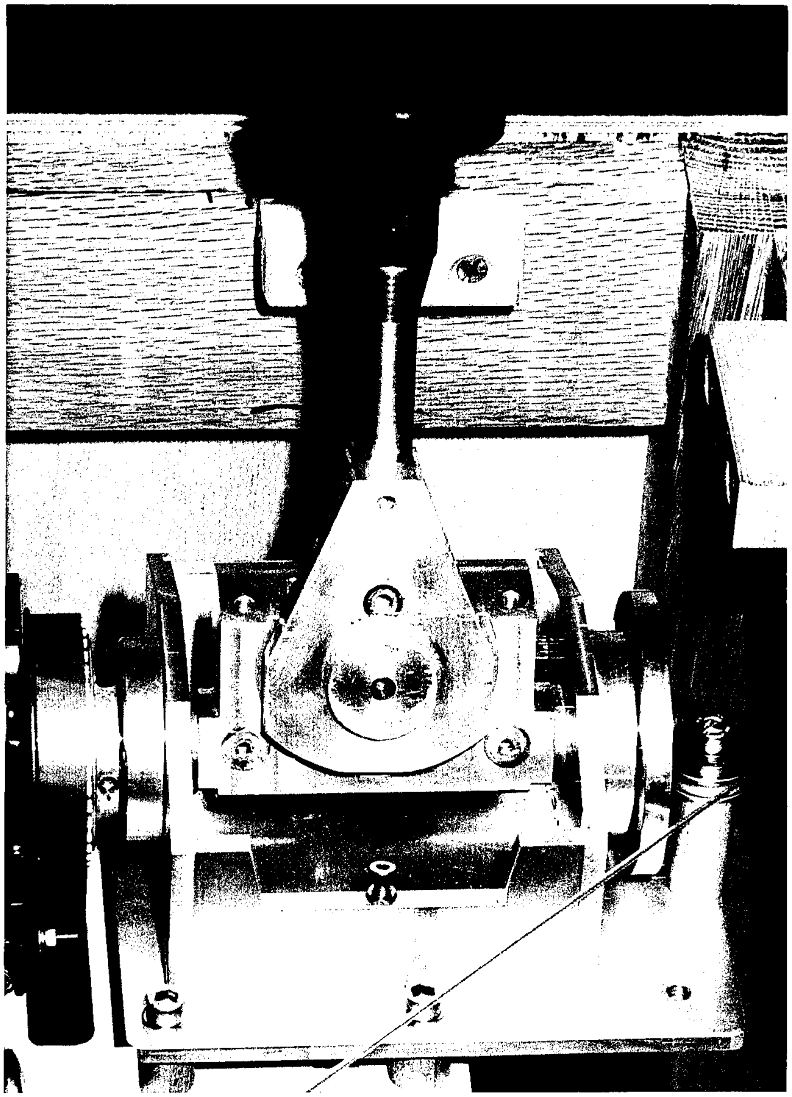

Fig. 3 The (active) joystick with its electro-engines used in the experiment.

The subject was seated at a console, in which a monitor and control devices were installed. Control actions of the subject were fed into the model computer. The joystick extended 10 cm above its pivot and could be moved by forces as represented in Fig. 2, which enabled subjects to move it without difficulties with their wrist (range of the stick: ± 30°). All task conditions involved this force-position characteristic. The required deflection of the stick for following the target optimally did not exceed 10° over all task conditions and scenarios. Right and left deflections resulted in right and left rotations of the camera, fore- and backward deflections changed camera pitch and thereby the distance of the footprint of the camera on the terrain. Forward movements produced decrease an backward movements produced increase of this viewing distance. The relation between joystick movements and rotations of the camera was for position control

1 : 1 pitch as well as for heading. For speed control, 1° of stick movement resulted in 0.09°/s of camera motion around both rotation axes.

The right arm rested on the housing of the electro-engines of the stick. Forces of the active joystick were provided by two BBC Brown Bovery AG electro-engines QK 140-2 with 2 kW static capacity and a 4 kW dynamic capacity. Steering forces of each of the two degrees of freedom were provided by one of the electro-engines. The forces necessary to counteract the interventions of the active system were as depicted in Fig. 2. For control of the joystick one PC was equipped by a Digital to Analog en Analog to Digital convertor. In the passive interface conditions, the same standard isometric joystick was used (see Fig. 3).

2.6 **Procedure**

Subjects served for one 1-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.

Practice

Practice began with a briefing as to the nature of the experiment. Subjects were not informed about the details concerning the assistance provided by the active interface. In essence they were told that the update rate would be slower and that the manner of camera control with the joystick would differ sometimes.
Subsequently, subjects practiced in 3 blocks of 400 s each, two blocks involved a passive interface and one block involved the active interface. During pilot experiments these amounts of practice proved to be sufficient to attain a stable task performance. Subjects practiced only with the control dynamics that were administered in the experimental trials. All practice trials were conducted with an update frequency of 10 Hz. Between the practice blocks subjects relaxed while their peer subject was practicing. The best subject of the day got a small bonus in prospect.

Experimental blocks

The Experimental part consisted of 8 blocks, 4 in the morning and 4 in the afternoon. For each condition two blocks were run. Each experimental block started with a small warm-up trail which took 120 s. Subsequently three trials of 240 s. each, involving the same condition were carried out. Subsequent trials were separated by a 90 s rest period. Hence, each condition consisted of 6 trials, three run in the same block in the morning and three likewise in the afternoon. The order of the 4 conditions (blocks) in the morning and afternoon was the same. The order of conditions was balanced between subjects. Familiarization and experimental trials were separated by rest periods of 90 s. In the first 10 s. of each trial the camera was automatically focussed on the target. Following that

period the subjects had to take over the job. Therefore, the first 20 s of each trial were not considered for data analysis.
This interface used inherent system "knowledge" concerning UAV motion in order to assist a camera operator in tracking an object moving through the landscape below. This landscape was sensored by the video camera attached to the UAV-platform and presented to the operator on a monitor display.

2.7 Data analysis

The tracking data were analyzed by a 2 (Interface) × 2 (Update frequency) × 2 (Steering difficulty) × 6 (trial) ANOVA with steering difficulty as a between-groups variable. Since the BSMI list does not provide an absolute criterion for workload, making only relative comparisons possible, the BSMI scores were analyzed by two separate 2 (Interface) × 2 (Update frequency) × 6 (Trial) ANOVAs only involving the within-subject variables.

3 RESULTS

3.1 Tracking scores

Table I shows the mean RMS error data in arc minutes for the three independent variables.

Table I Mean RMS error data in arc minutes for the three independent variables.

	Active interface		Passive interface	
	Velocity	Position	Velocity	Position
5 Hz	4.20	15.48	5.04	39.96
2 Hz	8.22	37.68	10.80	79.86

A main effect of interface showed that subjects performed substantially better with an active system, that corrected for UAV translations and provided feedback about this assistance through the joystick [F(1,14)=21.1, $p<0.001$]. This significant result counted for both position ($p<0.005$) and velocity control ($p<0.005$), although, as can be seen in Fig. 4, the difference between these difficulty conditions was much larger for position control than for velocity control [F(1,14)=17.2, $p<0.005$].

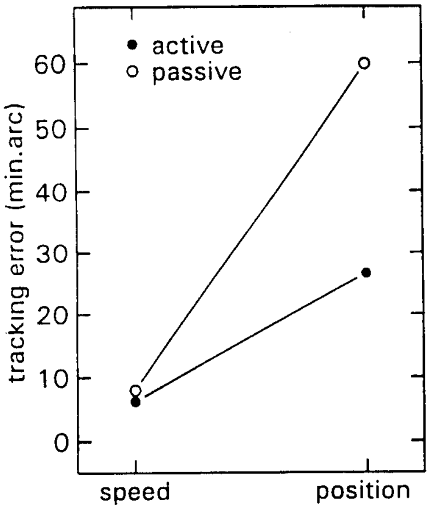

Fig. 4 Tracking performance as affected by interface type and control difficulty.

The data also showed a main effect of update frequency. With 5 Hz tracking performance was superior relative to 2 Hz [F(1,14)=12.4, $p<0.005$]. Fig. 5 demonstrates that this effect also interacted with difficulty of control dynamics, that is, a more pronounced effect of update frequency for position control than for velocity control [F(1,14)=6.6, $p<0.05$]. Though, separate analyses showed that the update frequency effect was significant for velocity ($p<0.005$) as well as for position control ($p<0.05$).

It should be noted that the overall positive effect of the active interface (17.5) is equal to the general effect of update frequency (17.9).

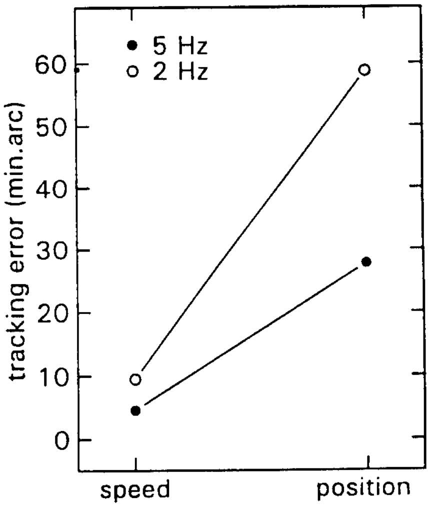

Fig. 5 Tracking performance as affected by update frequency and control difficulty.

There was a pronounced main effect of control dynamics, showing that velocity control resulted in better performance than position control [F(1,14)=28.7, $p<0.0005$]. As has been described above, this effect interacted both with interface type and with update frequency. There was no second-order interaction among these variables.
In order to check the data on possible effects of training or fatigue, trial number was also incorporated in the analysis. This showed a significant higher mean error in trial 2 and 5 for position dynamics. It appeared however that this resulted from a few occasions in which subjects completely lost the target from the screen. Corrected for these outliers, no consistent effect was found, i.e., after the training sessions the position data were stable over the succeeding experimental trials. For velocity control, after the first run in which tracking performance was relatively poor there was no clear trend to be seen in the data.

3.2 Mental workload scores

For the velocity-control group no difference was indicated between the active and passive interface. A higher update rate, however, was experienced as requiring less effort than the lower update rate (F(1,7)=1.87, $p<0.02$]. Furthermore, a significant trend was found indicating a gradual reduction of effort over subsequent trials. For the position-control group tracking with the active interface was judged as less effortful than with the passive interface [F(1,7)=14.03, $p<0.01$. This group also judged the 5 Hz conditions as less demanding than the 2 Hz conditions [F(1,7)=8.01, $p<0.05$]. Finally, an affect of trial number showed that the first and second trial, the task was judged as more effortful than the succeeding trials.

4 DISCUSSION AND CONCLUSIONS

The state of technological possibilities in automation has released man from having to perform manifold low-level subtasks that are a necessary condition for the effective operation of complex man-machine systems. However, there still remain several elements which *as yet* a human operator does better than any machine. Thus man still has to be included in a control system to employ his sensory and pattern recognition capacities, his versatility, his conception of possible (unexpected) future states of the system, and his possibilities of choice among these states (Kelley, 1968). In general, appropriate automation of lower-level loops of human-machine systems yields more opportunity to devote attention to higher-level processes and thus to exercise a broader span of control over multiple-task elements. For the specification of requirements for such systems, the central question is what can be automated and how should the division of labor between the human operator and the automaton be distributed.

In this connection, the present study was conducted to evaluate the possible benefits of partial automation in a simulated UAV task environment. UAVs are a typical exponent of recent development in complex man-machine systems characterized by a high degree of semi-automation. The present experiment focussed on the task of the camera operator of the UAV, who may be assisted by an "intelligent" interface in tracking a *moving* target with the camera mounted on the *moving* UAV platform. The crux of the present experiment was the fact that automation only concerned one element of an integral tracking task. One kind of error, i.e., the angle between the target and the center of the camera, originated from the combined effects of two kinds of motion, i.e., target and platform motion. Hence, the system took over only one part of the multiple, independent disturbance inputs. In part of the experimental conditions (active interface) the platform component of these inputs was automatically compensated for by the system, whereas in other conditions the operator had to null all kinds of motion (passive interface). In the former case, the operator had to superimpose joystick movements required to track the moving target over the corrections (and joystick movements) already initiated by the system.

The data showed that subjects performed substantially better with an active system, that corrected for UAV translations and provided feedback about this assistance through the joystick. Apparently, the subjects had no difficulty in maintaining control; i.e., "following" the active stick while superimposing self-initiated control movements over the system-interventions.
These system-initiated stick movements should not only be regarded as potential harmful for task performance. They also provided extra haptic information concerning camera motion, and it may be supposed that this indirectly enhances *situational awareness*[3] of the operator. That is, the operator receives more information about where he is looking, given the combination of camera rotations and UAV translations and rotations.
Furthermore, tracking performance with an update frequency of 5 Hz was clearly superior relative to 2 Hz. Hence, the difference between what is presently technologically realistic and what may be attained in the near future may be regarded as a serious step forward. The magnitude of the active-interface effect appeared equal to the update-frequency effect. Since there was no interaction between both interface variables, the positive effects of active joystick and a higher update frequency may be regarded as additive. Therefore, as a general deduction, it is safe to conclude that the provision of the presently used, rather simple, active system will enhance the performance of the human-machine system by the same extent once more. Furthermore the positive effect of both partial tracking automation and update-frequency elevation increased with the difficulty of the tracking task. Hence, benefits of update frequency enhancement and semi-automated tracking will be the greatest under difficult tracking conditions.

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[3] Situational awareness can be defined as the perception of aircraft orientation and position in space and time together with an apprehension of the environmental (threat, targets), flight, and system conditions.

The BSMI-scores indicated that for the difficult position-dynamics condition both semi-automation and frequency increase resulted in a lower degree of experienced mental effort in task performance. For the velocity-dynamics group, such an effect was only seen for update frequency. Because this absence of an effect of semi-automation for the velocity-dynamics group was not reflected by the error data it may be caused by the more subtle effects of the active interface relative to the visual effects of the frequency manipulations. This is in accordance with the point that during pilot studies, it appeared necessary to increase the gain of the stick in order to prevent that strong haptic cues concerning active joystick motion started to interfere with the subject-initiated joystick manipulations required to compensate for the motions of the target. Apparently, too strong system interventions diminish the operators' feeling of personal exertion of influence. According to Schumann (1994) this always requires a fine-tuning of continuous support, involving an adjustment of the signal characteristics of the support to the driver's internal model of the system.

This message is also in line with a point made by Kelley (1968). He stressed that continuous active signals disturb the operator's "internal model" of the regular steering dynamics and thereby will interfere with the efficient operation of any control process that is extended by a mechanical device. This idea has affected the nature of active devices evaluated in experiments—that is, providing discrete warning signals instead of direct (continuous) correcting movements on critical occasions (e.g., Rule & Fenton, 1972; Schumann, 1994). On the basis of the present data, this account of Kelley (1968) may be regarded as a little too strongly formulated. Although the present data do not allow any definite conclusions with regard to the occurrence of negative transfer between an internal "active control model" and an internal "passive control model" of subjects, the data indicate that the positive effects of semi-automation seemed to be relatively strong, given the low degree by which subjects experienced the occurrence of active system-initiated tracking movements[4]. Kelley's point seems particularly relevant for active systems that become rarely active only at particular critical instants. In that case, the system parameters instantly change such that the operator has to utilize two different control models, each of which must be activated at the proper time. According to Schumann (1994) unwanted drivers' reactions to such sudden intrusions may be prevented by implementation of perceptible, but not too strong signal characteristics, which was supported by our pilot data.

Otherwise, one may argue that counteracting reactions on instantaneous system support may be precluded when the operator clearly is informed about when the active or the passive control model is the most appropriate. This may be accomplished by an external signal or by very strong signal characteristics of system activations. Especially in the latter case tactile or haptic information by system-

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[4] With this conclusion it should be taken into account that for each subject the time of tracking with the continuous aid of the active system was equal to the time under passive conditions and that both task conditions were of equal novelty to the subjects. Therefore, it may be assumed that the eventual negative transfer effects between both conditions was about equal or symmetric.

initiated joystick displacements may be valuable for making these kinds of decisions. In this connection, a promising question for further research concerns how well people can discriminate between self-initiated and system-initiated movements of a joystick and what the optimal "ratio" of both should be. If people are able to discriminate well between the two kinds of movements, active joysticks only operating at particular (critical) intervals should not necessarily lead to disturbances of the internal control model. This may be particularly relevant for the possibility of providing additional haptic cues in teleoperated systems. Such augmented information especially may be crucial in critical tasks, such as recovery, or during scouting missions in which low-altitude flight is required. Also during driving on the ground or when using remote manipulators—in which interactions with the direct environment of the remote system are much more prominent than in flight—more information concerning vehicle attitude may be particularly valuable. Further research may also determine whether or not such feedback is always necessary. In many situations, an operator probably does not need to be aware about the help that is provided by the system in order to be able to attain the ultimate control goals (Kelley, 1968). An example of such "closed loop" assistance is the gyroscopic stabilization of a camera during rotations of a UAV platform.

Recent studies (e.g., Van Breda & Passenier, 1993; Chavand et al., 1988; Mestre et al., 1990) focussed on spatial orientation, or "situational awareness" problems in remote-control situations. These problems arise by the fact that it is difficult for stationary operators—who generally use a visual display as the main source of spatial information—to convert the visual transformations on the display, generated by the combined effects of platform- and camera motion, into egocentrical route knowledge. This lack of "situational awareness" may be compensated by providing augmented *visual* proprioception (literally: self-perception) concerning platform and camera motions. This would especially be helpful in missions with poor visual feedback (flying above see, hazy weather) and/or when the camera operator has to fly a UAV by himself. A possible solution in such situations would be the presentation of a visual "grid" or texture over the outside image. This additional structure would generate clear perspective optical transformations, termed optic flow or motion perspective (Gibson, 1950, 1966, 1979). These transformations can be analyzed in a few basic components. These basic components independently specify UAV translations and UAV or camera rotations, whether or not in combination (e.g., Koenderink, 1986; Kappé & Korteling, 1994) and thereby enhance the separate perception of vehicle and camera attitude in a environment. When such a grid is positioned at a certain height above the ground, it may also be an aid in the perception of ground speed and altitude during low-level flight or during recovery.

The experiment was set up such that eventual order-effects caused by training or fatigue could be taken into account. Apart from a relatively poor performance in the first trial for the velocity-dynamics group, tracking performance did not show clear order effects. This means that the differential effects of the investigated interface variables will remain over extended periods of practice. In contrast, the overall BSMI-scores showed a gradual decrease in mental effort over subsequent trials. Apparently, with practice the subjects felt that the task became less demanding, although their concrete performance remained equal. These results are in line with previous studies documenting easy adaptation of controllers to augmented haptic cues via an active control device (Schumann, Löwenau & Naab, 1994; Roscoe, 1980).

The present study showed that camera control in a UAV can be enhanced by an intelligent interface with an active joystick that provided haptic (proprioceptive) information. Such an interface may be conceived as compensating for the lack of direct visual and/or proprioceptive information that can be used in normal aircraft. Also in controlling the *attitude* of an teleoperated system, which, in comparison with a manned system, does not provide direct exteroception and proprioception, the lack of situational information is apparent. For example, while flying a manned aircraft the wide visual field provides the pilot an immediate indication of the slightest attitude change (visual proprioception). Small translational accelerations of the aircraft are felt by the vestibular organs. The aerodynamic forces on the control surfaces are felt by the pressure and stretch receptors of the hand and arm. Speed can be inferred from aerodynamic noise or by the sound of the engine. All this proprioceptive information will be lacking in a normal teleoperated vehicle, making manual flight more difficult.

It should therefore be investigated which proprioceptive information contributes most to the effectiveness of manual control and in what way it should be made operational. Next to active sticks, items that should be taken into account are: 3D (virtual) acoustics, motion platforms, wide field-of-view cameras, additional or augmented visual cues, and virtual world imagery. The possible benefits of these alternatives for teleoperated systems together comprise a promising and prominent field of human factors research.

REFERENCES

Breda, L. van & Passenier, P.O. (1993). *An Exploratory Study of the Human-Machine Interface for controlling a Maritime Unmanned Air Vehicle.* Report IZF 1993 A-10, Soesterberg, NL: TNO Human Factors Research Institute.

Chavand, F., Colle, E., Gallard, J.P., Mallem, A. & Stomboni, J.P. (1988). Visual assistance to the teleoperator in teleoperation and supervision situations. *Proceedings of the International Symposium on Teleoperation and Control,* Bristol, pp. 237-248.

Denaro, R., Kalafus, R. & Ciganer, P. (1989) Target Acquisition in the UAV Environment. In: *AGARD Conference Proceedings* 436. Guidance and Control of Unmanned Air Vehicles. NAVO, Neuilly sur Seine.

Eisen, P.S. & Passenier, P.O. (1991). *Technology Status of Unmanned Air Vehicles.* Report IZF 1991 A-31, Soesterberg, NL: TNO Human Factors Research Institute.

Gibson, J.J. (1950). *The perception of the visual world.* Boston, MA: Houghton Mifflin.

Godthelp, J. (1990). *The use of an active gas-pedal as an element of an intelligent driver support system: literature review and explorative study.* Report IZF 1990 B-17, Soesterberg, NL: TNO Human Factors Research Institute.

Hendy, K.C., Hamilton, K.M. & Landry, L.N. (1993). Measuring subjective workload: when is one scale better that many? *Human Factors*, 35, 579-601.

Kappé, B. & Korteling, J.E. (1994). *Time to contact in driving simulators.* Report TNO-TM in press, Soesterberg, NL: TNO Human Factors Research Institute.

Kelley, C.R. (1968). *Manual and Automatic Control.* New York: John Wiley & Sons.

Koenderink, J.J. (1986). Optic flow. *Vision Research*, 26, 161-180.

Mestre, D., Savoyant, A., Péruch, P. & Pailhous, J. (1990). In search for realistic visualizations for human computer interaction in spatially oriented process control. *Proceedings of the Fifth European Conference on Cognitive Ergonomics (ECCE5)*, Urbino.

Poulton, E.C. (1974). *Tracking skill and manual control.* New York: Academic.

Roscoe, S.N. (1980). *Aviation Psychology.* Ames: The IOWA State University Press.

Rule, R.G. & Fenton, R.E. (1972). On the effects of state information on driver-vehicle performance in car following. *IEEE Transactions on Systems, Man, and Cybernetics*, 2, 630-637.

Schumann, J. (1994). *On the Use of discrete proprioceptive-tactile warning signals during manual control—the steering wheel as an active control device.* Internationale Hochschulschriften. München: Universität der Bundeswehr, Waxmann.

Schumann, J., Godthelp, J. & Hoekstra, W. (1992). *An exploratory simulator study on the use of active control devices in car driving.* Report IZF 1992 B-2, Soesterberg, NL: TNO Human Factors Research Institute.

Schumann, J., Löwenau, J. & Naab, K. (1994). The active steering wheel as a continuous support for the driver's lateral control task. In: *Vision in Vehicles V* (in press). Amsterdam: North-Holland.

Veltman, J.A. (1991). *Mentale werkbelasting bij Vliegers: theoretisch kader en literatuuroverzicht* (in Dutch). Report IZF 1991 A-33, Soesterberg, NL: TNO Human Factors Research Institute.

Veltman, J.A. & Gaillard, A.W.K. (1993). *Evaluation of subjective and physiological measurement techniques for pilot workload.* Report IZF 1993 A-5, Soesterberg, NL: TNO Human Factors Research Institute.

Wagenaar, W.A., Frankenhuizen, J., Vos, J. & Flores d'Arcais, G.B. (1984). There is no induced motion at near-threshold velocities. *Acta Psychologica*, 55, 295-313.

Womack, J. & Steczkowski, A. (1987). *Review of past and current trials and uses of unmanned air vehicles.* Tech. Report HSD-TR-87-011, Brooks AFB, TX, USA: Human Systems Division.

Zijlstra, F.R.H. (1993). *Efficiency in Work Behaviour; a design approach for modern tools.* Delft: Delft University Press.

Zijlstra, F.R.H. & Doorn, L. van (1985). *The construction of a subjective effort scale.* Report Technische Universiteit Delft, Fac. Wijsbegeerte en Technische maatschappijwetenschappen.

Zijlstra, F.R.H. & Meijman, T.F. (1988). Subjectieve mentale inspanning: gekontroleerde informatieverwerking en/of "executie resource control". In: Deelman, B.G. & Mulder, G. (Eds.), *Nederlands Psychologisch Onderzoek 3.* Lisse: Zwets & Zeitlinger.

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15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

With the rapid development of automatic control techniques a central question is how the division of labor between the human operator and the automaton should be optimally distributed. In this connection, the present study focussed on an intelligent, semi-autonomous, interface for a camera operator of a simulated Unmanned Air Vehicle (UAV). This interface used inherent system "knowledge" concerning UAV motion in order to assist a camera operator in tracking an object moving through the landscape below. This landscape was sensored by the video camera attached to the UAV-platform and presented to the operator on a monitor display. The semi-automated system compensated for the translations of the UAV relative to the earth. This compensation was accompanied by the appropriate joystick movements ensuring tactile (haptic) feedback of these system interventions. The operator had to superimpose camera movements over these system actions required to track the motion of a target (a driving truck) relative to the terrain. Consequently, the operator remained in the loop; he still had total control of the camera-motion system. In order to investigate the effects of this semi-automation over a broad range of task situations, the tracking task was carried out under two conditions of update frequency of the monitor image and control mode difficulty.

The data showed that subjects performed substantially better with an active system. Apparently, the subjects had no difficulty in maintaining control; i.e., "following" the active stick while superimposing self-initiated control movements over the system-interventions. Furthermore, tracking performance with an update frequency of 5 Hz was clearly superior relative to 2 Hz. The magnitude of the active-interface effect was equal to the update-frequency effect. On the basis of effects of difficulty in steering dynamics, it was also concluded that the benefits of update frequency enhancement and semi-automated tracking will be the greatest under difficult tracking conditions. Mental workload scores indicated that for the difficult tracking-dynamics condition, both semi-automation and frequency increase resulted in less experienced mental effort in task performance. For the easier dynamics this effect was only seen for update frequency.

16. DESCRIPTORS	IDENTIFIERS
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Automation	Semi-automation
Manual Control	Simulation
Proprioception	Unmanned Air Vehicles
Tracking	
Visual Ergonomics	

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