Hyperstereopsis in Night Vision Devices: basic mechanisms and impact for training requirements

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ABSTRACT

Including night vision capabilities in Helmet Mounted Displays has been a serious challenge for many years. The use of "see through" head mounted image intensifiers systems is particularly challenging as it introduces some peculiar visual characteristics usually referred as "hyperstereopsis".
Flight testing of such systems has started in the early nineties, both in US and Europe. While the trials conducted in US yielded quite controversial results, convergent positive ones were obtained from European testing, mainly in UK, Germany and France. Subsequently, work on integrating optically coupled I² tubes on HMD was discontinued in the US, while European manufacturers developed such HMDs for various rotary wings platforms like the TIGER.
Coping with hyperstereopsis raises physiological and cognitive human factors issues. Starting in the sixties, effects of increased interocular separation and adaptation to such unusual vision conditions has been quite extensively studied by a number of authors as Wallach, Schor, Judge and Miles, Fisher and Ciuffreda. A synthetic review of literature on this subject will be presented.
According to users' reports, three successive phases will be described for habituation to such devices: initial exposure, building compensation phase and behavioral adjustments phase.
An habituation model will be suggested to account for HMSD users' reports and literature data bearing on hyperstereopsis, cue weighting for depth perception, adaptation and learning processes, task cognitive control.
Finally, some preliminary results on hyperstereopsis spatial and temporal adaptation coming from the survey of training of TIGER pilots, currently conducted at the French-German Army Aviation Training Center, will be unveiled.

Keywords: "See through" Helmet Mounted Displays, night vision, hyperstereopsis, telestereoscope, adaptation to rearranged vision, human factors, training

1. INTRODUCTION

Hyperstereopsis, usually referred in the scientific literature to as "Increased Inter Ocular Separation", is directly linked with Helmet Mounted Sight and Display (HMSD) - "See Through" concepts (type 2). With "see through" systems, sensor images are superimposed on direct vision of the outside scene using a semitransparent combiner, implying that sensors are not located in front of the eyes. In non see through Night Vision Goggles (NVG, type 1), sensors and displays are located in front of the eyes, blocking direct vision of the outside scene and allowing only some limited "look around" capabilities.

Due to implementation constraints, early HMSD systems, as the IHADSS, were only monocular, displaying only thermal imagery and raising binocular rivalry issues. Binocular "see through" NVGs, as "cats'eyes" or "eagle eye", appeared in the late eighties and, following technological improvement, several binocular HMSDs capable of raster, stroke and I² images display were flight tested from early to mid nineties. All these systems used side mounted Image Intensifier

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Tubes, usually generating a ratio of 4 between I² tube spacing and standard Inter Pupillary Distance (IPD) as seen in figure 1. Besides the benefits of providing a binocular vision, such integrated sight and display systems aimed at reducing head worn mass, allowing better HMD balance and providing day/night capabilities for operation of aircraft weapon systems. Visor projection of sensor images also allowed to take the best of peripheral vision and improved further mass distribution.

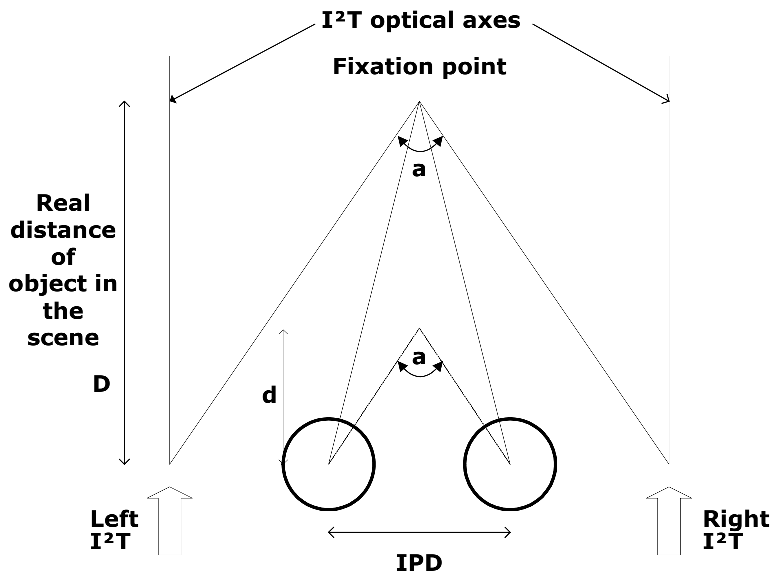

Fig. 1: Convergence requirements and distance perception with See through HMDs using Side mounted I² tubes.
Distance between the I²T tubes is greater than IPD. An observer fixating a target at distance D must converge as though the target was located at distance d. d is the perceived distance of the target in the scene.

Developmental flight testing of such systems essentially took place in US, UK, Germany and France. On the whole, testing in the US yielded some controversial results, while flight test conducted in Europe produced rather positive evaluations.

McLean & Rash [1] reported on early testing of the Honeywell INVIS respectively conducted at Fort Belvoir on an AH-1S and at Fort Rucker on the front seat of an AH-64. Results obtained on the AH-1S were extremely negative. Hyperstereopsis and sensor placement on the side of the helmet were strongly criticized and the system was globally rated unsafe. However, no details are available on the way pilot trained during initial exposure and how human factors issues pertaining to this kind of sensor arrangement have been understood and addressed. Testing in Fort Rucker was based on comparison between two see through systems (INVIS and Eagle Eye) and standard ANVIS. No difference was reported in flight performance between the different systems, though subjective assessment revealed a preference for standard ANVIS.

German experience [2, 3] is based on the Knighthelm helmet manufactured by GEC (UK) and later with the TOPOWL® helmet (THALES, Fr). Initial AVT flight testing in Manching, GE concluded as follows on the hyperstereopsis issue [3]: “Altitude evaluation errors occur when looking through the combiner (without sensor image) and also when using both sensors. This effect however is not surprising with image intensifiers. The above-mentioned altitude evaluation errors imply an additional risk when flying with the HSI. It can however be reduced significantly when using overlapping symbology, by familiarizing oneself with this phenomenon, and also through intensive training”.

Later testing conducted in Buckeburg [4] with a TOPOWL® HMD in 2001 gave quite similar results: “The approximately double base distance of the objective lens in relation to the eye creates a false range feeling at close distance. The objects seem closer than they effectively are which proves a nuisance particularly during hover flight when evaluating the aircraft altitude. The impression gained is one of a low hovering altitude. Since this however is a deviation to the “safe

side", no security breach was registered. Once the pilot gets conscious of this wrong impression, he compensates for it after relatively few flight hours". It should be noticed the lack of accuracy on the required time in using the system to achieve a satisfactory level of adaptation.

French developmental testing was conducted on a two year period from 1995 to 1997. Human factor results [5] obtained during the flight test of the HMSH and HSMDB, precursors of the TOPOWL® HMD, have been reported during the SPIE Aerosense meeting in 1998. It has to be noted that a strong emphasis was given on human factors issues and especially hyperstereopsis throughout the development phase. Positive results obtained in laboratory testing (using stimulation techniques) [6] were confirmed during flight tests as follows: "In-flight results show that, on initial exposure, some perceptual differences with NVGs were consistently reported by all pilots. It is of importance to note that initial misperception is going in a "safe" direction. After a few hours of flight (estimated between 5 and 10 for most pilots), adjustment of the internal model was completed, as predicted, and pilots returned to nominal performance obtained with NVG." [5]

The human factors team involved in the testing strongly insisted on the need for a progressive training and introduced quantitative assessment techniques to follow pilot habituation to the new vision condition. Unfortunately, the full evaluation was only completed by one pilot, though the other ones were globally in agreement with the findings. The potential high variability across pilots along the adaptive phase was not further investigated.

A proper training appears to be a key issue when using that kind of system. See through HMDs using Side mounted I² tubes are extremely different from standard NVGs and it can be suggested that they require a specific habituation, even for pilots having extensive experience of night flight.

Reviewing literature data on hyperstereopsis mechanisms and effects is an essential step to correctly understand the possibilities and limits of such visionic systems.

2. THEORITICAL DATA

2.1. Literature update on hyperstereopsis

Helmholtz [7] designed the original telestereoscope in 1857 on the purpose to increase the relief of distant objects. This optical device enhanced binocular disparity and apparent depth of 3D objects with an arrangement of mirrors optically increasing their subject's effective interpupillary distance, leaving monocular sources of depth information unaffected. Helmholtz believed that through the scope subjects viewed an exact reduced scale model of the world.

Wallach et al. [8, 9] were the first to explore the modification of depth perception under telestereoscope viewing. The optical arrangement was made in such a way that convergence required for fixation on the axis of rotation is the same as without the telestereoscope (figure 2), however convergence for 3D objects is altered, points of the object seen nearer or farther than the axis of rotation need respectively greater or less than normal convergence. In contrast, little change in the stimulus for accommodation is induced by the telestereoscope and monocular sources of depth information are unaffected. After 10 minutes of viewing a rotating wire cube through the telestereoscope, the apparent depth of the cube was decreased relative to that experienced before rotation. Wallach interpreted this effect in terms of a learning process, or perceptual learning, induced by the conflict between cues altered (disparity) or unaffected (kinetic depth effect) by the telestereoscope. Adaptation to perceptual rearrangement would result from the diminishing of the conflict between the two paired cues, with recalibration of disparity by the kinetic depth effect and changes in the relation between disparity and perceived depth. Wallach reported the modification of perceived depth to be rapid, partial (reaching 20% of the theoretical maximum), cumulative (time of exposure) and transferable to other objects. Modification of perceived depth also declined rapidly with return to normal vision ("unlearning") or less rapidly with eyes closed ("forgetting").

Fisher & Ebenholtz [10] used a pre exposure/exposure/post exposure design with the optical device of Wallach. They found that adaptation of depth perception could occur in the absence of kinetic depth effect or disparity and was a secondary consequence of changes in distance perception. They also suggested that the depth and distance aftereffects derived from oculomotor adaptation (accommodative system or its coupling with the vergence system), because aftereffects were found in monocular exposure but not with artificial pupils.

Adaptation based upon physiologic properties of the oculomotor system, in contrast with Wallach's perceptual recalibration theory was also proposed by Fisher & Ciuffreda [11]. They studied depth and distance perception, tonic accommodation, tonic vergence and accommodative vergence gain following a 30 min exposure of naturalistic viewing with the telestereoscope. The optical device used in the experiment increased twofold convergence required for all viewing distance (figure 3), whereas the stimulus for accommodation was almost unchanged, eliciting a conflict between vergence and accommodation. An increase in depth and distance of the target was observed after exposure. No change in accommodative vergence gain occurred, but a significant increase in tonic vergence was obtained.

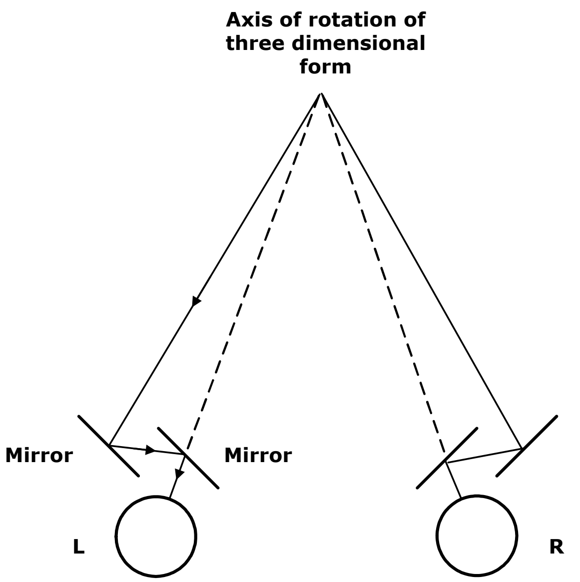

Fig. 2: Wallach's telestereoscope (1963).
Solid lines represent reflected light-path to the observer's eyes. Dashed lines indicate the lines of sight of the eyes.
Inner and outer mirrors are not exactly parallel. Convergence angle is the same as without the device for fixation on the axis of rotation.

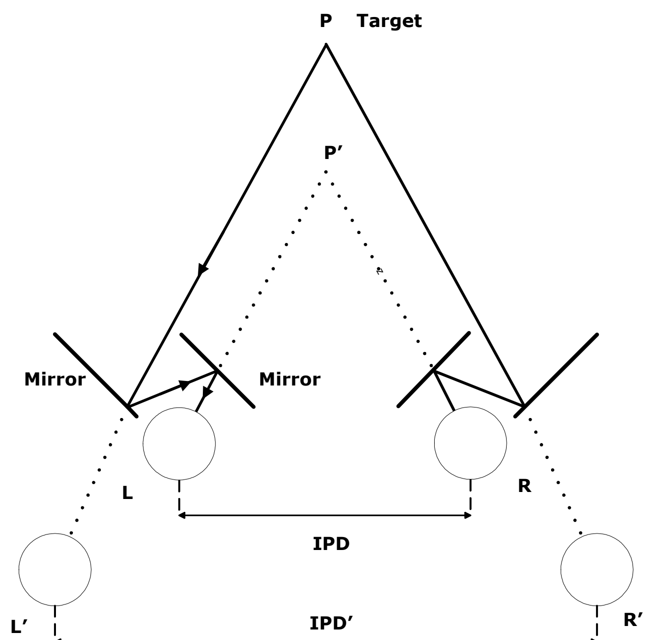

Fig. 3: Telestereoscope used by Fisher & Ciuffreda (1990).
Solid lines represent reflected light-path to the observer's eyes.
Inner and outer mirrors are parallel. Fixation on point P requires the same convergence as fixation on point P'.

By means of lens and base-out prisms, Ebenholtz & Fisher [12] found that distance adaptation occurs in conditions requiring sustained fixation. Paap & Ebenholtz ascribed this effect to "eye muscle potentiation" [13]. Prolonged convergence of the eyes to a nearby object produces a change in the tonic state of the extraocular muscles. Ocular position is maintained even after relaxation. Fusing on a target requires a change in the oculomotor innervation level to compensate for the phoria (or dark vergence), giving the subject an inexact ocular position signal and a change in perceived distance. Von Hofsten [14] proposed a similar explanation: apparent distance of an object depends on the effort required to fuse on the object. This effort depends on the difference between the phoria and the distance of the object.

According to the accommodation and vergence control model proposed by Schor [15, 16], accommodation and vergence systems are composed of fast and slow elements. The slow fusional component of the vergence system develops slowly during sustained convergence (more than 30s) and shows an incomplete relaxation after occlusion of one eye. Distance perception is derived from the levels of accommodation and vergence. Therefore any shift in the phoria alters distance perception.

Rapid adaptation of egocentric distances generated by a shift in absolute convergence level was also reported after exposure to base-in or base-out prisms [17].

Whatever the precise explanation for adaptation (perceptual learning versus physiologic properties of the oculomotor system), oculomotor adjustments such as phoria or/and modification of the cross-couplings between accommodation and

vergence occur under telestereoscope viewing. Two cross-links connect accommodation and vergence sytems: accommodative vergence and convergence accommodation, which are modeled as fast or phasic elements [16].
The telestereoscope induces a potential oculomotor conflict between accommodation and vergence, calling for changes in gain in the coupling between accommodation and vergence. The accommodative-vergence gain is characterized by the AC/A ratio, defined by the magnitude of vergence response associated with a unit change in accommodation.
Judge & Miles [18] reported increases in the stimulus AC/A ratio following a 30 min exposure to periscopic spectacles similar to a telestereoscope. Similar results were obtained in a later study, with decreases and increases in the gain of vergence accommodation and accommodative vergence responses [19], accompanied by vertical shifts of accommodative vergence responses curves in some subjects.
Such changes were not obtained in the study of Fisher & Ciuffreda [11], revealing only an increase in tonic vergence. Bobier & Mc Rae [20] demonstrated that changes in the cross-coupling between accommodation and vergence could be obtained only with alternate fixation during telestereoscope exposure period. If fixation is maintained on a narrow range of distances during exposure, tonic vergence modification is sufficient to challenge the conflict between accommodation and vergence.
Interindividual differences in oculomotor adaptation were noticed in most studies.

An interesting way of studying adaptation to hyperstereopsis closer to field conditions is to provide active task to subjects. Judge & Bradford [21], van der Kamp et al. [22] studied telestereoscope viewing through one-handed catch. They found rapid adaptation to telestereoscopic vision [21, 22], considerable interindividual differences and long term adaptation effect [21]. Authors suggested that having subjects performing an active task during telestereoscope exposure period would exert some pressure on adaptation [22]. They concluded that adaptation would result in reevaluation of the telestereoscope altered binocular information rather than ignoring them [21, 22]. Since weights assigned to binocular information are adjusted with each catch and since binocular and monocular weights are interdependent, reevaluation would include binocular and monocular informations [22]. Authors also noticed the role of size constancy of familiar objects during these experiments.

The flexibility of adaptation to vision constraints and to the available visual cues has been noticed in the literature review. The mechanisms determining the relative importance of each visual sources of information must be presented.

2.2. Cue weighting for space perception

Even though measuring stereoscopic acuity is the central assessment for testing the ability an observer has to perceive the word in three dimensions, depth perception in ecologic conditions cannot be restricted to stereoscopic vision. Multiple and redundant visual cues for perception of space are available when exploring a natural scene.
Some are quite independent from visual signal processing and directly depend on the optical parameters of the eye. The oculomotor components of the eye have to be adjusted to ideally deliver the environmental light signal onto the retina. Such is the case for accommodation when focusing an image on the retina and also for binocular vergence projecting space centered on both retinae. Both these factors are closely interdependent. Their influence on depth perception has been intensively presented previously in the paper.
Other visual cues for three-dimensional space perception demand a visual processing of the light signal. Such is the case for retinal disparity, providing stereoscopic vision, or for the so-called monocular cues. These latter cues do not require the comparison of both retinal projections; they emerge from processing the visual signal delivered by a unique eye. The majority of these cues are based on form perception and on the relative arrangement of these forms in the scene. They are the following:

- Contributors to perspective effect such as object angular size that decreases as observation distance increases while texture density varies in opposite way;
- Linear perspective results in a vanishing point with convergence of parallels towards infinity;
- Elevation in the visual field with increasing distances, the upper visual item laying on horizon and being the most distant visible component of earth;
- Overlapping cues occur when two objects fall in a relative alignment; The partially masked object is perceived further away;
- Motion parallax based on the comparison between the relative visual flow supported by objects in the scene with regards to their distance while the observer is moving,

Such a range of cues offers visual perception a description that is both redundant and progressively enhanced by the spatial relations of the elements in a scene. All their informative values can be highly variable according to environmental and/or individual factors.

A scene, rich in elementary objects will offer many different cues, while a poor environment (bad weather conditions, night vision goggles that make the signal to noise ration lower than in optimal natural viewing conditions) will make monocular cues disappear.

Some depth cues are independent of form perception because they rely on an analysis of elementary characteristics of light signal like local contrasts. It is the case for stereoscopic vision and motion parallax. Besides, it is the dissociation between form perception and stereoscopic vision that is used in stereoscopic acuity tests developed for clinical use and that rely on random dot stereograms [23]. One must emphasize finally on the importance of motion parallax in aeronautics where the aircraft in generally moving in the environment. Building an appropriate 3D perception in flight is largely based on developing an expertise in processing the differential visual motion generated by the over-flown objects. This is especially the case for nap of the earth flight as objects are denser and closer. The specific heavy weight taken by motion parallax cue when in flight has a major incidence on distance evaluation when in stationary flight because it is missing.

Observation distance is in itself a factor of variation in the relative weight assigned to the informational cues. Thus, proximal observation of space implies higher binocular disparities and favors stereoscopic vision. Convergence and accommodation are also only effective at close distances. In contrast, longer distance observation offers comparable projection on both retinae, hence lowering the efficiency of retinal disparity, turning stereoscopic vision into a lesser informative input while monocular cues are essential.

The relative weight of visual cues for space perception also depends on individual factors, which define the observer's cognitive style. The benefit provided by each cue for distance estimate is personal and that defines the current weight allocated to that cue in the perceptive integration the observer performs while looking at a scene.

3. DEEP ANALYSIS OF FLIGHT TEST REPORTED DATA

The habituation process HMSDB users have already reported seems to follow a three step procedure mainly involving physiological and perceptual mechanisms on initial exposure and high level behavioral issues in the final stage.

a) The first phase: initial exposure

During initial exposure pilots experience a number of classical illusions related with the spatial arrangement of the sensors. Standing on a flat ground, they typically feel they are at least one third shorter than their actual height, which makes walking difficult. After approximately 30 minutes of walking around they become accustomed to the scene and usually feel they are walking in a ditch. Distance perception is severely modified, with objects appearing to be far closer than they really are.

Crater or ditch illusions are constantly reported during initial flight, along with distance and height estimations errors. Errors are in the "safe" direction as pilots feel closer and lower by a factor of approximately 2 in regard of real distance. When landing pilots often report the feeling that the lowest part of the aircraft "is going underground" and they are "sitting on the runway". The closer the objects are, especially within 20 meters, the higher the difficulties are.

During this phase, size constancy which usually greatly contributes to egocentric distance perception seems to induce temporary illusions. Field of view of the virtual image appears smaller than what pilots are accustomed to with conventional ANVIS. Size of distant known objects, as aircraft and vehicle, are also misjudged, appearing smaller than reality.

Comparing these observations with laboratory results, it appears quite legitimate to hypothesize that error perception and related visual illusion in this phase are directly linked to modification of convergence need induced by the separation between the sensors. Modified afferent vergence signals appear to initially dominate other visuals cues of relative distance, such as angular size, in the distance and depth evaluation process. Pilots have to exert tight cognitive control to compensate for spurious perception and usually have to make several corrections to achieve the intended maneuver. They have to revert to some kind of feed back control, as the flight mental model developed through previous training becomes inadequate in the prevailing vision conditions.

b) The second phase: building compensation phase

Following the initial exposure, pilots usually report an intermediate phase where they gradually regain better situation perception from familiarization flight exercise. Achieving accuracy in flight maneuvers during this phase still implies some additional attention and workload, but perception of height and distance progressively improves. Pilots feel increasingly more comfortable but usually report that return to nominal perception remains incomplete. During this phase, risk may be increased because pilots are less conscious of danger while oculomotor conflicts and illusions decrease.

This phase could be described as a “reinterpretation” of vergence cues towards consistency with monocular visual cues and associated cognitive models. The basic mechanisms appear very similar to other sensory habituation processes, such as the reinterpretation of otolithic cues during space flight: subjects exposed to weightlessness experience first orientation illusions such as being upside-down (inversion illusion), then sensory rearrangements occur with increased contributions of visual (vection, local indicators of the walls or the floors), tactile and internal (alignment of their trunk) cues as information for orientation [24, 25].

A new action/perception model is progressively built up, allowing to perform the flight tasks with the require accuracy and appropriate anticipation of the situation.

Return to quasi-nominal flight performance in term of distance and height estimation in open space has been reported as acquired through this step after 5-6 hours.

c) The final phase: behavioral adjustments

Despite the basic sensory readjustment occurring in the visual system in regard of distance and depth perception, additional changes are necessary to recover a fully satisfying level of performance through acquisition of modified rules and skills for flying the aircraft (according to the Rasmussen’s skill-rule-knowledge framework of cognitive control [26]).

This phase overlaps with the previous one and implies a reorganization of motor and cognitive processes used to fly the aircraft. It includes adjustment of visual references acquisition strategies (outside and inside the cockpit, head movements). Due to the location of the sensors, pilots have to rebuild new references to operate the aircraft in various conditions. This is definitely the most challenging phase especially in regard of operations in confined areas. Difficulties to overcome may be exacerbated by the design of the cockpit and canopy (struts, bows…). This case of adjustment is sensitive to pilot seat (front/rear) and specific training has to be carried out for each seat.

In this phase it could be hypothesized that behavioral adjustments and task management build up could probably bear more on the side of the vehicular model than on the perception model.

A cognitive model can be suggested to account for the users’ reports and the literature experimental data bearing both on hyperstereopsis and on cue weighting for depth perception.

4. CONCEPTUAL APPROACH

The model presented in this section combines previous suggestions regarding various mental components of task control:

- A cybernetic approach reveals efficient due to the error feedback learning concept [27]
- Part of it also contributes to the perceptual adaptation model proposed by Young [28]
- Finally, considering the skill-rule-knowledge model for task management elaborated by Rasmussen [26] at a global activity level reveals fruitful.

This approach results in a synthetic view of the various human factor phenomena occurring when a pilot, previously trained for night flight with NVGs, is offered an HMSD system to complete the mission.

Flying a helicopter can be considered as a complex task only handled after a progressive training. Mission preparation activates a series of elementary procedures temporally organized in the operator’s working memory. Among the generic cognitive models the pilot has built from prior experience and stored in mind, such as driving, walking, fly helicopter, fly with NVGs, play golf…, only the relevant ones are intentionally selected to perform the task and instantiate the procedures.

Acting at a skill controlled level of task management allows minimizing the cognitive resources involved in the task. Based on the pre-activated models –NVG and Aircraft- and due to the current step of the mission (procedure in progress), a combination of sensory inputs is inferred as an expectation in order to valid the appropriate achievement of

the procedure. This expectation is shown as a vector V' (s', ve', vi', a') in figure 4. Comparison is performed between the configured expectation and the effective perception of the actual situation, based on a subjective optimal integration process run on the multisensory inputs, figured as V (s, ve, vi, a). Refine basic models, both of NVGs and of the aircraft, resulting from an extensive experience of night flight in a wide variety of circumstances, jointly with a good knowledge of the running mission provide relevant expectations. This characterizes the expert pilot. So, matching between the two vectors triggers action delivery on the aircraft controls in agreement with the script of the mission. This is the feed forward loop as the current task is labeled as completed, allowing the next elementary procedure to be on focus.

In the case of an HMSD familiarization phase, the expectation based on a NVG model does not match the effective perception due to the hyperstereoscopic bias and that turns off the skill based control of the task. Both basic models are questioned. From knowledge argues the pilot tries to keep the aircraft model unaffected (reconsidering the aircraft model means regarding as false the depth and altitude data delivered by the displays). So, the NVG model must be declared invalid. A new night vision system model must also be built, referred to as the HMSD model in figure 4. Its initial structure is suggested by giving sense to vector V, in the current flight configuration. But a cognitive model of a tool is only useful when it can be used to generate expectations for shortcoming states or events in order to recover a skill based control. So, vector V'' (s", ve", vi", a") comes from closing the perception and control loop. A continuous analysis of the perceptual inputs when acting on the aircraft controls (e.g. staring at the surrounding terrain when landing) results in improving the accuracy of expectation delivery. At this stage, the relative weight assigned to the various sensory inputs (amongst visual depth cues and across sensory modalities) is reconsidered and/or sensory data are recalibrated.
This is the feedback control of the task, requiring a high cognitive resource involvement. Only at the end of this close loop control can the elementary procedure be declared as completed and the following procedure may be initiated.

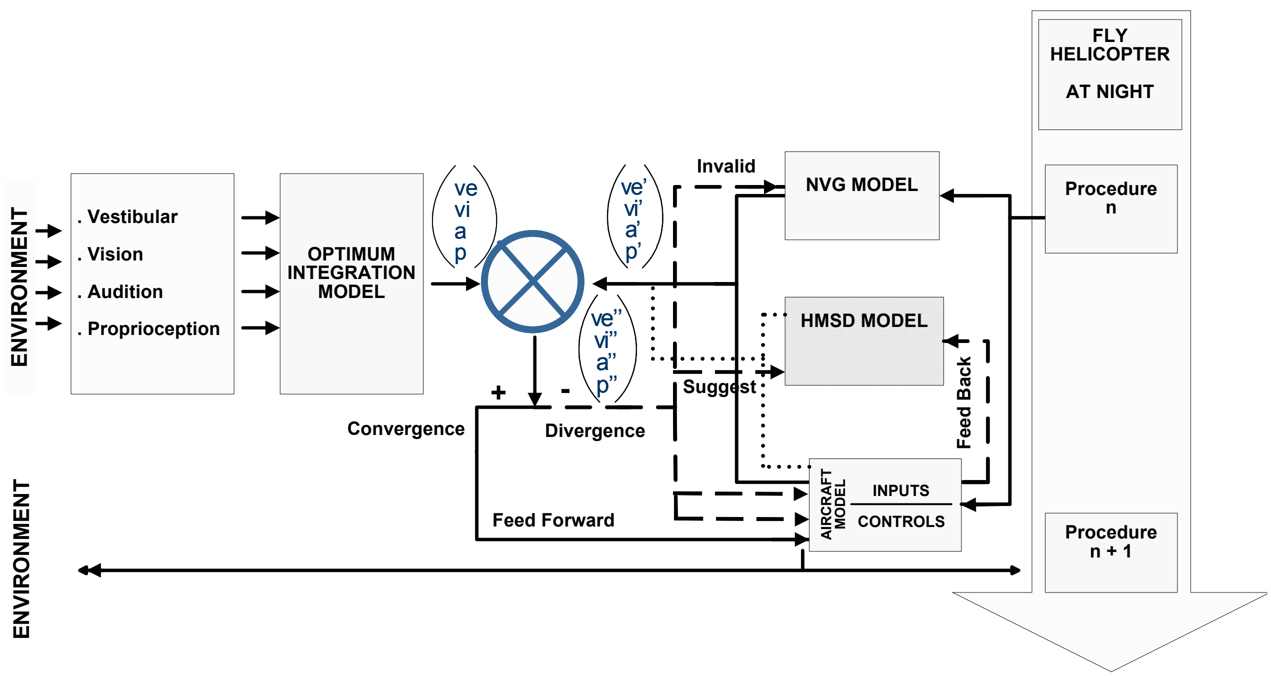

Fig. 4: Habituation model to HMSD (acquisition of the "fly helicopter at night with HMSD" model).
Before introduction of the new night vision device, congruence of expected and effective perceptions provide a feed-forward control of action. With exposure to HMSD viewing, the expectation based on a NVG model does not match the effective perception due to the hyperstereoscopic bias, the NVG model becomes invalid and an new HMSD model is build through a feedback mode.

Such an habituation model is interesting to consider as it highlights a set of key points for optimizing the process:

- Repetition of similar flight conditions helps refining the new equipment model. Poorly documented expectations can be tested and adapted through the feedback control if required.
- The close loop process emphasizes the benefit drawn by an active habituation to the equipment. Held noticed that interacting actively with the optically rearranged environment provides optimal conditions for visuomotor adaptation [29]. Continuous changes in sensory inputs, adjustment of predictions when actively applying controlled commands on the system greatly structure the new equipment model [21, 22]. A passive exposure to the same flight conditions may be far behind in efficiency and a longer time may be required to acquire a comprehensive model.
- Lack in the close loop effect may dramatically impairs the model construct leading to erroneous interpretation of a given set of multisensory inputs. Hover appears as a plausible candidate for the occurrence of misperception: the sensory motor loop is frozen and the most powerful depth cue in flight (i.e. motion parallax) is neutralized.
- Consolidation of a recently elaborated new equipment model may be rather disrupted if the previous NVG model has undercurrent reactivation. The assumption would be a bias affecting the new equipment expectations in the NVG ones. In other words, adaptation to an HMSD may be slowed down if classic NVG flights are inserted in the training.
- The NVG model can only be declared as invalid if there is no doubt on the aircraft model. Thus, this later model must be robust. This point is critical when a new equipment is delivered jointly with a new aircraft. This is the case for the Tiger helicopter and the TOPOWL® HMSD. So, night flights may not be a major priority at the early stage of pilots' training.
- A point not clarified by the suggested habituation model is whether the new equipment model is an extension of the NVG one or a new additional model in the large list of the elementary models stored the pilot's cognition. Adding a degree of freedom in the initial NVG model may favor the positive transfer of expertise to the new flight conditions but may not be necessarily the most efficient solution. Highly sophisticated models may never be entirely handled. In either case, the time required to recover a correct depth perception when shifting from one night tool to the other remains obscure.

All those hypothesis and questions led to more extensively investigate the habituation phase in a large group of novice HMSD users.

5. SURVEY OF TRAINING OF TIGRE PILOTS

The first "Tigre" helicopters are currently being shipped to our Army aviation and personnel are being instructed with its avionics, systems and especially its novel Helmet Mounted Display: the "TOPOWL®". The expected impact on distance perception having been reported during test flights [5], a longitudinal evaluation has been set up at the Ecole Franco-Allemande (French-German Army aviation training facility for the Tiger Helicopter) in Le Luc en Provence to assess the way in which adaptation to the novel visual display happens and evaluate the potential risk during training.
Pilots have to habituate both with the helicopter and its Helmet Mounted Display. According to the habituation model presented above, acquisition of the helicopter model must be fully achieved in daytime conditions before exposition to a new night vision system. Day flights are therefore preferable at the beginning of the training.
All pilots undergoing training with the Tiger are suggested to be included in this study. This means the experimental assessment of distance perception is incorporated in their already busy training schedule and as such was designed to be non-intrusive and as close as possible with standard Tiger flight training procedure. Special attention is paid to perform a quantitative assessment of distance perception allowing direct comparison across pilots.
During prior reconnaissance flights, typical spots in the over-flown terrain that demand distance evaluation have been selected. In the course of their night training on standard flight circuits, trainees have to evaluate "double distance" (D2) or "double heights" (H2) [6] on these designated spots when prompted by the instructor. All D2 or H2 estimates are collected and consigned within the progress sheet of the trainee with his: hours of flight training, hours of night use of the TOPOWL® and hours of use of other night vision devices. After each night flight, trainees fill a first questionnaire in relation to their just completed flight (weather, complexity…), their visual perception of the environment and possibly on

vision disorders (fatigue, eye straining, headache…). They also fill a second questionnaire the day after to record the events (sleep problems, nervousness, and difficulties with distance appreciation…) of the night following their flight.

The study has started early this year and data are still collected at very this moment. Delays are expected in the collection of data, because it is not a laboratory study, inserted early in the delivery process of the novel aircraft. Completion of the experimental flights at night depends mainly on weather conditions, operational constraints, aircraft availability, novel technology whereabouts…
As of today, preliminary results that still need to be confirmed show a maximum of distance appreciation errors at very short range (under 10 m) and especially during landing. No reliable estimate can be made regarding the time course of the helmet adaptation process and the level of variability across users.

6. CONCLUSION

"See through" HMDs using side mounted I^2 tube provide major human factors achievements such as optimizing mass balance and improving peripheral vision. However, increased separation of side mounted I^2 tubes introduces perceptual differences with other night devices such as NVGs. Pilots have to habituate with a new night vision device and the NVG flight performance model has to be replaced by the HMSD flight performance model.
Literature review has individualized two fundamental mechanisms for adaptation to hyperstereopsis: oculomotor adjustments and perceptual learning.
Further laboratory studies will be conducted to identify precisely the optical constraints induced by HMSD, dissociate them and investigate their repercussions on visual functions. These experiments will also be expected to help for a better understanding of the nature, mechanisms and properties (temporal features, interindividual differences) of the adaptation process to such devices.
Longitudinal survey of habituation of a population of pilots may allow to characterize the different phases of adaptation to HMSD, identify critical phases for security and investigate interindividual differences in order to determine the optimal conditions for training.

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