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An Analysis of Mental Workload in Pilots During Flight Using Multiple Psychophysiological Measures

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Piloting an aircraft is a complex task that places demands on several aspects of a pilot's cognitive capabilities. Because of the multifaceted nature of flying, several measures are required to identify the effects of these demands on the pilot. Several psychophysiological measures were recorded so that a wider understanding of the effects of these demands could be achieved. Heart rate, heart rate variability, eye blinks, electrodermal activity, topographically recorded electrical brain activity, and subjective estimates of mental workload were recorded. Ten pilots flew an approximately 90-min scenario containing both visual and instrument flight conditions. To determine the reliability of the psychophysiological measures, the pilots flew the same scenario twice. The responses during the 2 flights were essentially identical. Cardiac and electrodermal measures were highly correlated and exhibited changes in response to the various demands of the flights. Heart rate variability was less sensitive than heart rate. Alpha and delta bands of the brain activity showed significant changes to the varying demands of the scenarios. Blink rates decreased during the more highly visually demanding segments of the flights.

Piloting an aircraft is a highly complex task that requires the pilot to be proficient in numerous skills. Flying is a dynamic pursuit that at times can place great

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demands on the pilot's cognitive capabilities. High levels of cognitive demand can lead to errors with catastrophic outcome. Increasing our knowledge of the effects of the various demand levels encountered during flight can help avoid errors. It is necessary to design systems and develop training regimens and flight procedures that will reduce cognitive demands to not exceed the capacities of the human operator. Data from typical flights can help us develop an understanding of the usual demands placed on pilots. This information can assist us in forming the standard against which future data are compared. It also permits comparisons with data from unusual circumstances. This requires measures that are sensitive to cognitive workload so that one can assess the effects of system demands on the operator.

Several psychophysiological measures have been shown to be sensitive to the cognitive requirements of complex task performance (Hankins & Wilson, 1998; Wilson, 2001, 2002; Wilson & Eggemeier, 1991). Heart rate has been the most widely used in flight research (Roscoe, 1992). It typically increases with higher levels of mental workload. Eye blinks have also been used in flight research to investigate the demands of the various aspects of flying (Hankins & Wilson, 1998; Wilson, Fullenkamp, & Davis, 1994). Blink rate tends to decrease with increased visual demands in the dynamic flight environment. Electrodermal activity (EDA), although widely studied in the laboratory, to my knowledge has not been recorded during actual flight (Boucsein, 1993). Brain activity is another good candidate measure for monitoring the cognitive demands of flight. The brain is responsible for receiving and processing sensory information, making decisions, and initiating actions. An electroencephalograph (EEG), a representation of the brain's electrical activity, is often used as a measure of brain engagement during cognitive tasks (Davidson, Jackson, & Larson, 2000; Wilson & Eggemeier, 1991). The EEG spectra are analyzed to determine the levels of activity present during different cognitive activities. By simultaneously recording from several scalp sites, one can generate topographic maps that show the distribution of the electrical activity over the scalp. Inspection of these topographic maps can reveal patterns of activity that are useful for identifying the regions of the brain that are engaged in high-workload segments of flight. This study is among the first to utilize topographic EEGs during actual flight. Several investigators have recorded EEGs during flight (Caldwell & Lewis, 1995; Hankins & Wilson, 1998; Sterman & Mann, 1996; Wilson, 1993). Due to the complex nature of the cognitive requirements of flight and the functional organization of the human brain, different regions of the brain are more involved in some aspects of flight than others. For example, visual flight rules (VFR) and instrument flight rules (IFR) place very different demands on the visual system and higher level processing capabilities.

The complexity of flying requires that the pilot use numerous cognitive processes, and determining the pilot's mental workload requires more than one measure. Any one measure should not be expected to give full insight into the multifaceted nature of piloting. Besides examining the effects on individual measures one must also inspect the interrelationships among the measures. Although simulations provide useful data, actual flight data must be obtained to test the validity of the measures. This study used multiple measures of pilot workload to understand the complex nature of mental workload when pilots fly a complicated scenario.

Using general aviation aircraft and pilots permitted a flight scenario design that incorporated a wide range of flight activities. This "flying laboratory" approach provides much more latitude with the experimental design than when data collection flights are piggyback on operational flights. The characteristics of the operational flights are dictated by the agency owning the aircraft and may not completely fit research needs. It is not clear whether generalization is possible to other categories of pilots. However, one could assume that the pilots who participated in this study are at a skill level that would permit comparisons with pilots flying other types of aircraft who are at a similar skill level with those aircraft. Furthermore, one of the main goals of this project was to determine the reliability of the psychophysiological data recorded during flight by having the pilots fly the same scenario on two separate days. To my knowledge this sort of replication has not been previously accomplished. To establish the utility of psychophysiological measures one must demonstrate that they produce consistent results from day to day. Another objective was to record EDA during the flight to ascertain its utility for flight research.

METHODS

Ten general aviation pilots participated in the study. Only male pilots volunteered to participate. Their mean number of total flight hours in all aircraft types was 1,317 with a range of 158 to 5,400 hr. They had a mean of 114 hr in the Piper Arrow with a range of 13 to 270 hr of experience. Their mean age was 43 with a range of 30 to 64 years. During the flights they flew a Piper Arrow in a prescribed scenario that lasted approximately 90 min. The Arrow is a single-engine aircraft with retractable landing gear. The scenario was divided into three major parts: VFR, IFR, and high-speed (HS) IFR. To simulate IFR conditions the pilots wore goggles that restricted their vision to the aircraft instrument panel. The goggles, or "foggles," impaired forward vision but permitted downward viewing of the instruments. The speed of the aircraft was increased by 30 kt for the HS segments. The same basic scenario was used for all flights unless air traffic control directed deviations. A total of 22 two-min segments were identified for analysis. The segments were preflight baseline, preflight checklists, engine start, VFR takeoff, VFR climb-out, VFR cruise, VFR air work, VFR approach, VFR touch and go, VFR climb-out, IFR air work, IFR cruise, IFR hold, IFR distance measuring equipment (DME) arc, IFR instrument landing system (ILS) tracking, IFR missed approach, IFR climb-out, IFR HS hold, IFR HS DME arc, IFR HS ILS tracking, landing, and postflight baseline. Psychophysiological data were averaged over these 2-min segments for analysis.

Electrocardiographic (ECG) data were collected from electrodes placed over the sternum and the seventh intercostal space on the left side of the chest. Electrooculographic (EOG) data were collected from electrodes placed above and below the right eye and lateral to the outer canthus of both eyes. The skin under the ECG and EOG electrodes was cleaned with alcohol and mildly abraded prior to application of the reusable tin electrodes. R waves of the ECG data were located, and the interbeat intervals (IBIs) between successive R waves were calculated. These data were evaluated for missed and extra beats, which were corrected. Heart rate variability (HRV) in mid- (0.06–0.14 Hz) and high (0.15–0.40 Hz) bands was calculated using the IBI data with the MXedit software (Delta-Biometrics, Inc.). EEG data from 29 scalp sites were recorded using reusable tin electrodes embedded in a stretch cap. A mastoid reference was used for the EEG recordings. The EEG electrode impedances were below 5k ohms. The EEG, ECG, and EOG data were amplified, digitized (256 Hz), and filtered (0.1–50 Hz) online using a Smart Helmet system (Sam Technology, Inc.). Eye blinks, horizontal movements, and head movements were also recorded by accelerometers (*x, y,* and *z* axes), which were used to correct the EEG data for artifacts using the Manscan software package (Sam Technology, Inc). The EEGs from 2-min segments were submitted to spectral analysis and divided into the standard bands of delta (1–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz). Relative power in these bands was statistically analyzed in relation to changes from the preflight baseline segment. These data were spatially smoothed, and the Laplacian operator was applied to reduce low spatial frequencies prior to plotting of the topographs. Paired comparisons were made for each electrode remaining after the Laplacian procedure.

EDA was recorded from electrodes placed on the arch of the right foot, 3.2 cm apart. The skin under the EDA electrodes was not cleaned or abraded prior to electrode application. Grass EC33 electrode cream was used with the EDA electrodes, which were reusable Ag/AgCl. To determine whether the leg movements associated with controlling the aircraft artifactually influenced the EDA responses from the foot, electromyographic (EMG) data from the calf of the right leg were recorded. A Vitaport II recorder collected the EDA, EMG, and aircraft altitude data. The EDA data were analyzed using the EDR_Para 3.6 software package from the University of Wüppertal. The number of EDA responses, amplitudes, rise times, recovery times, and tonic levels were analyzed. The EMG data were spectrally analyzed, and the power levels were submitted to the same statistical analyses as the EDA data.

Because physical activity necessarily increases cardiac activity it is possible that movements associated with piloting are responsible for heart rate effects. An actigraph was worn on the left wrist to record movements during the flights. If changes in heart rate were caused by body activity, then one might expect wrist movements to be highly correlated with heart rate.

The global positioning system and altitude were recorded to accurately log aircraft position and altitude during flight. The pilots gave their subjective estimates of mental workload at the end of each of the 22 segments. A 0-to-100 scale was used, with 100 indicating extremely high workload.

For all of the measures, pairwise comparisons of the 22 segments were performed using the paired *t* test. The customary strategy of using the analysis of variance (ANOVA) first was not used because of the large number of segments. It was felt that significant effects could be hidden in an overall nonsignificant ANOVA. The flight segments were designed to differ. To determine the sensitivity of the measures, each segment was compared with the others. Due to the large number of tests only comparisons of $p = .01$ are reported. Even then, about six pairwise comparisons might be expected to be significant by chance only. Therefore, the interpretation of the results focuses on patterns of reactions instead of individual flight segments. Heart rate statistics were calculated on IBIs because of their known distribution properties. For explanatory purposes the data are reported in the more commonly used beats per minute.

Before each flight the pilots received a preflight briefing that explained the scenario. A safety pilot flew in the right seat on each flight. The participant was the pilot in command at all times. The minimal environmental conditions used to clear each flight were as follows: cloud ceiling at least 6,000 feet above ground level, 4 miles visibility, and wind of less than 10 kt.

RESULTS

The data from the two flights were compared to determine whether significant differences existed. The same pattern of responding was found for both replications of each type of data. There were almost no statistically significant differences between the data from the two flights for the psychophysiological data across the 22 segments. The list of significantly different segments was very small and consisted of postbaseline for heart rate, VFR cruise for actigraph, and IFR ILS tracking for the subjective rating data. Despite the large number of comparisons made with the 20 EEG electrode sites remaining after the Laplacian correction, four bands and 22 segments, only 17 comparisons were significantly different between the two flights. This is notable because the time between flights varied from several days to several weeks among the 10 pilots. Because the data from both flights were statistically equivalent, the data for each measure were pooled for the remaining analyses.

The group mean heart rates for the 22 segments are shown in Figure 1. Heart rate discriminated among three groups of segments. Peak rates occurred during takeoffs and landings. This high heart rate group also includes the touch and go and the missed approach segments. The heart rates show an intermediate grouping that includes preflight checklists, engine start, VFR cruise, VFR air work, IFR cruise, IFR hold, IFR DME arc, IFR climb-out, HS hold, and HS DME arc. The lowest heart rates are found during the pre- and postflight baselines. The IFR climb-out, HS hold, and HS DME arc segments are associated with lower heart rates than the preceding IFR segments of similar type. Although not statistically different, these reduced rates are interesting because the aircraft speed was increased during the HS segments. The HRV results show statistically significant

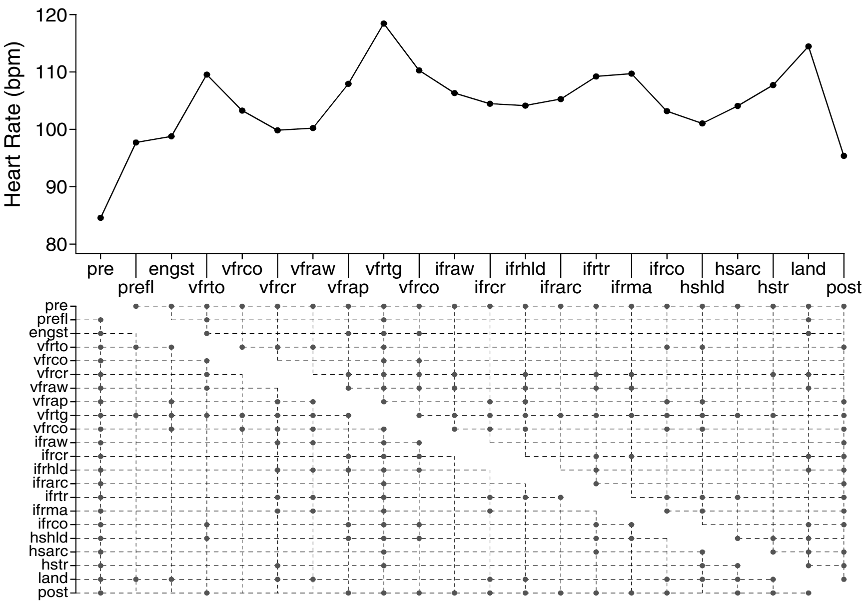

FIGURE 1 Mean heart rates from both flights across the 22 mission segments. The segment labels are as follows: pre = preflight baseline; prefl = preflight checklists; engst = engine start; vfrto = VFR takeoff; vfrcr = VFR cruise; vfraw = VFR air work; vfrap = VFR approach; vfrtg = VFR touch and go; vfrco = VFR climb-out; ifraw = IFR air work; ifrcr = IFR cruise; ifrhld = IFR hold; ifrarc = IFR DME arc; ifrtr = IFR ILS tracking; ifrma = IFR missed approach; ifrco = IFR climb-out; hshld = IFR HS hold; hsarc = IFR HS DME arc; hstr = IFR HS ILS tracking; land = landing and post-postflight baseline. The matrix below the graph represents paired comparison results. Dots at the intersection of the lines projected from two segments indicates a statistically significant difference of at least $p < .01$.

decreased variability for both the medium and high bands during only the VFR takeoff and the VFR touch and go segments (Figure 2). The preflight baseline is associated with slightly higher levels in both bands. The other flight segments are statistically equivalent.

Mean total EDAs are shown in Figure 3. The statistical results show three different segment groups. The VFR takeoff, touch and go, and final landing had the most EDA responses. The pre- and postflight baselines show the fewest EDA responses. The remaining 17 segments are essentially equivalent. The IFR missed approach is not in the highest group as it is with heart rate. Comparison with the heart rate figure reveals their very strong similarity. The correlation between the heart rate and electrodermal data is $r = .83$. The heart rate data show a larger number of significant differences among the various flight segments than the electrodermal activity. The EDA tonic level shows a linear decline from the beginning to the end of the scenario. The tonic level shows significant increases associated with VFR takeoff, VFR touch and go, and the final landing. The recovery times for the EDA responses during the VFR takeoff, VFR touch and go, and the final landing were significantly shorter than those during preflight baseline, preflight checklists, VFR climb-out, IFR air work, IFR DME arc, IFR ILS tracking, HS holding, and HS DME arc. EDA amplitudes and rise times exhibit few significant differences among the 22 segments. The EMG recorded from the calf

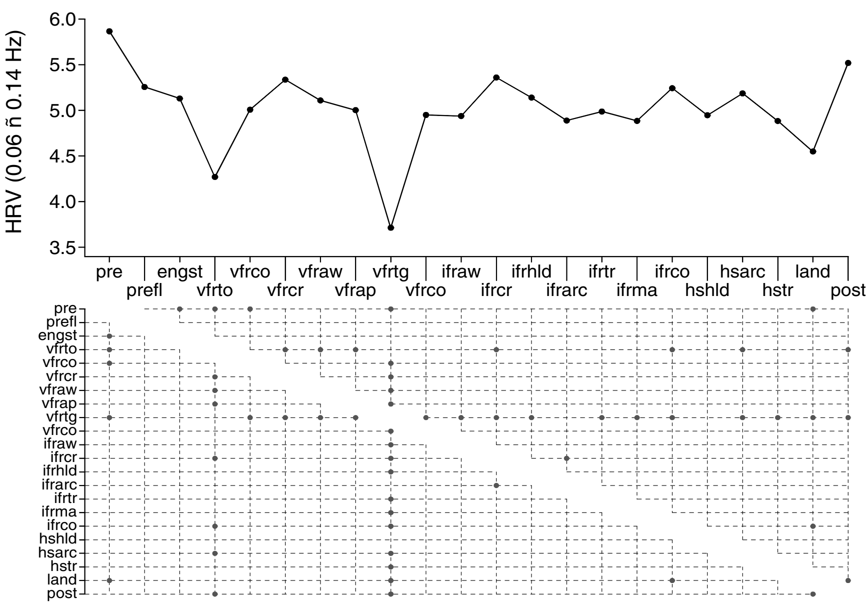

FIGURE 2 Heart rate variability in the medium band averaged across days and pilots for each mission segment. See Figure 1 for an explanation of the labels and matrix.

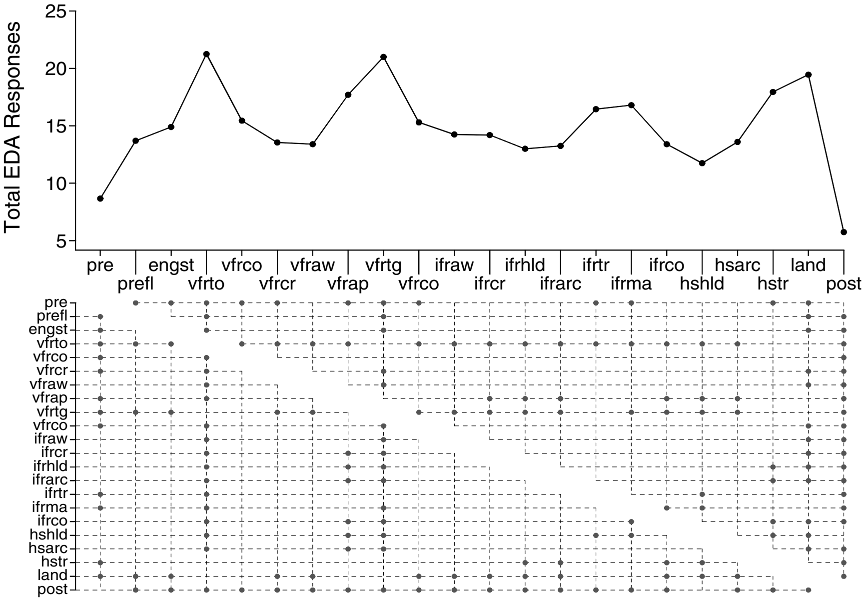

FIGURE 3 Total electrodernal activity responses for the 10 pilots averaged across both flights for each segment. See Figure 1 for an explanation of the labels and matrix.

does not show the same pattern of responding as the EDA. Leg movement artifacts represented by the EMG data are not responsible for the EDA effects.

Blink rates were found to be determined by the overall visual demands of the task the pilot was performing (Figure 4). The IFR and HS IFR conditions are associated with reduced blink rates. During these segments flight information was restricted to the cockpit instruments because the pilots were wearing the foggles. The VFR segments following takeoff also exhibit reduced blink rates. VFR approach is associated with higher blink rates as is the final landing. The higher blink rates during the VFR climb-out segment are also of note. Analysis of the blink durations yields few significant comparisons.

The actigraph data show the highest levels of wrist activity during the preflight checklists, engine start, and VFR touch and go. The preflight baseline is associated with the lowest levels of activity. The remaining 18 segments are statistically equivalent. The actigraph data are not highly correlated with the heart rate data ($r = .35$, $p < .11$)

The mean subjective mental workload data are displayed in Figure 5. There appear to be three related groups of segments based on the subjective data. IFR ILS tracking and HS ILS tracking produced the highest levels of mental workload. The easiest segments were the first six VFR segments. The remaining segments appear to form a middle difficulty group.

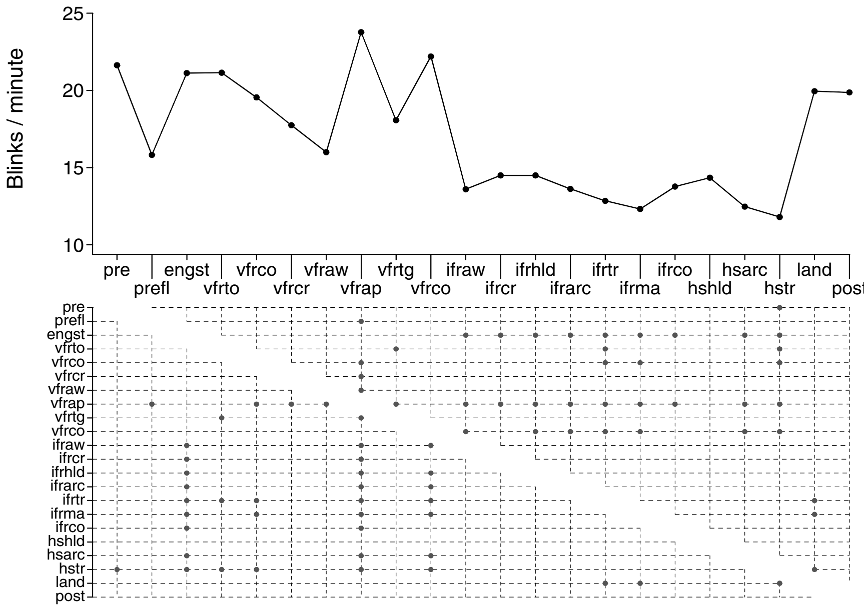

FIGURE 4 Mean blink rates for both flights for each of the 22 segments. See Figure 1 for an explanation of the labels and matrix.

Statistical analysis of the EEG alpha band was accomplished by comparison with the preflight baseline versus all other segments. These results show that the bulk of the changes were reductions in alpha band power over the parietal scalp (see Figure 6). The majority of significant overall decreases were found during the IFR segments. The most widespread decreases are associated with the landings, VFR touch and go, IFR missed approach, IFR climb-out, HS ILS tracking, and the final landing. There was a consistent involvement of the right parietal area, indicated by power reductions at electrode sites P4, P8, and PO4. Electrode site PO3 also showed significant reductions during the IFR segments. Delta band activity increased at electrode sites primarily over the central and parietal scalp when compared to the preflight baseline (Figure 7). VFR touch and go, final landing, and VFR takeoff are associated with the most sites showing delta band power increases. VFR approach, VFR climb-out, IFR air work, IFR cruise, IFR missed approach, and HS ILS tracking are also associated with significant increases in several electrode sites. The central scalp electrodes, C3, Cz, and C4, consistently showed increases in the delta band power during many segments, and P4 showed similar results. Significant reductions in beta band activity were found primarily during VFR takeoff, VFR approach, VFR touch and go, and final landing. The remaining segments showed few significant reductions in beta band activity. Only five segments showed increased theta band activity at a few scattered electrode sites; no consistent pattern is evident.

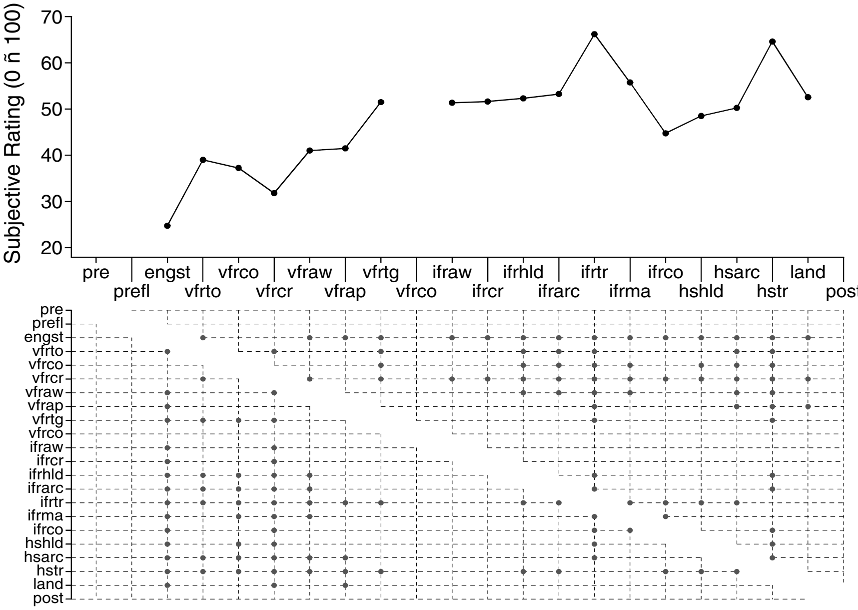

FIGURE 5 Subjective rating means from both flights. Ratings were not recorded for the segments without means. See Figure 1 for an explanation of the labels and matrix.

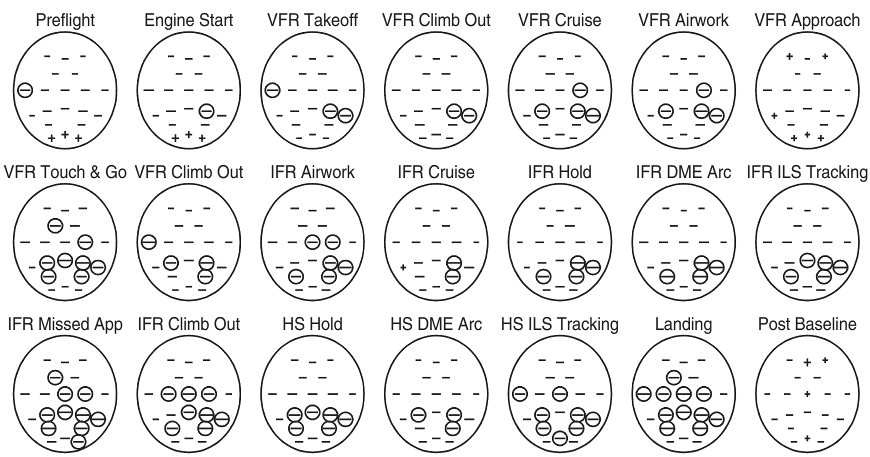

FIGURE 6 Results of the statistical analysis of the alpha band relative power. Each segment was statistically compared to the preflight baseline. The large circles represent the head with the front of the head at the top of the circle. The plus and minus signs indicate whether the mean relative power at an electrode site was larger or smaller than the same site in the preflight baseline data, respectively. The circled plus and minus symbols indicate a significant difference of $p < .01$ or smaller. The segments are labeled above each large circle.

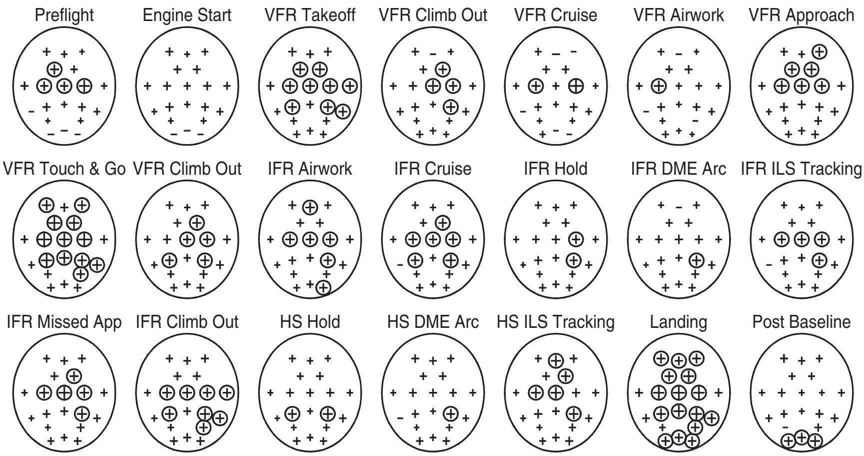

FIGURE 7 Delta band relative power statistical results. The data from each electrode and segment were compared with the preflight baseline data. See Figure 6 for an explanation of the symbols.

DISCUSSION

The results of this investigation demonstrate that psychophysiological measures recorded during flight produce patterns of activity that are consistent over a period of weeks. Until now it was only assumed that these data would be reliable. However, this assumption was based on the comparison of data across studies from different laboratories using different pilots, procedures, and aircraft. The data from this study demonstrate not only very high levels of consistency between the two flights but are also highly similar to the results of the earlier study from this laboratory (Hankins & Wilson, 1998). The scenario and aircraft type were the same in these two studies. Not only are the psychophysiological data highly reliable from day to day among the same pilots, but the overall results are also consistent with those from a different group of pilots who flew the same scenario with the same aircraft type. There are some differences in the results of the two studies. The earlier study reported significant increases in theta band power. The blink rate pattern changes are similar, but the earlier study found more statistically significant effects. However, the high degree of similarity reinforces the notion that psychophysiological data recorded during flight produce highly repeatable results.

Takeoffs and landings produced the greatest number of changes in the psychophysiological data. Heart rate, EDA activity, and EEG alpha and delta band activity all showed changes. This highlights the increased level of cognitive demand placed on the pilots during these important maneuvers. The involvement of both the peripheral and the central nervous system measures further emphasizes the high cognitive demands of these tasks. The heart rate and EDA response increases found during the takeoffs and landings are consistent with this interpretation (Boucsein, 1993; Hankins & Wilson, 1998). The reduced EEG alpha band power and increased delta band power found during takeoffs and landings are also consistent with previous data showing these responses to be associated with increased cognitive demand (Harmony et al., 1996; Sterman & Mann, 1996). Finding that segments with lower cognitive demands, such as cruise, are associated with the expected changes in these measures further supports this view. The data associated with the resting baseline periods reinforce this position. The data found during these periods of the lowest cognitive demand indicate minimal mental workload. The HRV results are interesting in that only the initial takeoff and the touch and go are associated with significant reductions in variability in both bands. The missed approach and final landing are not associated with significant decreases in HRV; in fact, the HRV to all other flight segments is essentially the same. The HRV was not as sensitive to the varied cognitive demands of flight as the other peripheral nervous system measures, such as heart rate and EDA (Veltman & Gaillard, 1996; Wilson, 1992).

Although commonly regarded as requiring increased cognitive activity, the takeoffs and landings are not associated with high subjective workload ratings. The two IFR tracking segments are responsible for the highest subjective ratings, and the takeoffs and landings are rated with the majority of flight segments in the middle range. The higher ratings may be due to the pilots' lack of practice with the ILS tracking. They do not typically fly the ILS tracking, and the subjective ratings may reflect this.

The HS IFR segments produced lower heart rates than the same IFR segments that were performed at a slower speed. This may be because the pilots had just flown the same conditions in the slower speed segments and thought that they knew what to expect with the higher speed conditions. This effect has been previously reported by Roman, Older, and Jones (1967) and Roscoe (1975). The same effect was noted in an earlier study (Hankins & Wilson, 1998), which lends weight to the reliability of psychophysiological data collected during flight. Due to the characteristics of the Piper Arrow, the increase in speed was 30 kt, which apparently is not sufficient to increase the cognitive demands on the pilots.

The VFR and IFR flight segments are associated with markedly different levels of blink rates. In VFR conditions the pilots could use visual information from outside the cockpit to aid them with navigation and altitude determination and also to verify their position as indicated by the cockpit instruments. During the IFR segments the pilots were totally dependent on the cockpit instruments for information about their location and altitude. This is a more difficult cognitive task and resulted in the decreased blink rates found during the IFR segments. Veltman (this issue) also reports higher blink rates during VFR conditions. Blink rates were found to be determined by the overall visual demands of the task the pilots were performing. The decline in blink rate during the VFR segments following takeoff is consistent with this interpretation in that those tasks required more attention to the cockpit instruments. This is evident during the preflight checklist segment, which is also associated with decreased blink rates. Performing the preflight checklists entails reading the checklist cards and changing or verifying cockpit settings. The higher blink rates associated with the two VFR landing segments—touch and go and final landing—may be due to transition blinking that accompanies eye movements from inside to outside the cockpit. During visual approaches pilots make use of visual information outside the aircraft to confirm their position by looking at the approaching runway. Then their gaze moves back to the instrument panel to verify speed and altitude. Eye movements such as these are often accompanied by eye blinks during the movements. This argument is supported by the lack of increased blinking during the IFR missed approach segment that did not permit transitioning the gaze from inside to outside the cockpit and did not generate increased blink rates. The reduced blink rates during visually demanding segments replicate our earlier findings (Hankins & Wilson, 1998). Others have reported similar results in simulators, which further supports the contention that blink rates are valuable measures of visual demand during flight (Veltman & Gaillard, 1996).

The high correlation between heart rate and EDA activity, as used in this investigation, suggests that these measures contain redundant information. The heart rate was more sensitive to the varying demands of flight in that it shows more statistically significant effects among the 22 flight segments. This implies that recording only heart rate may be sufficient. However, it is possible that a finer grain or different sort of analysis might reveal unique information available from the EDA data.

Examination of the topographical EEG data shows that a relatively few electrodes capture the main effects found during the flights. For example, alpha band reductions showing the effects of higher workload during many of the IFR segments are shown at P4, P8, PO4, and PO3 electrodes. However, data from additional electrodes, such as Pz and P3, would be needed to reveal the specific effects associated with the touch and go and final landing. Examination of the delta band data reveals a core of scalp electrodes (C3, Cz, C4, and P4) that exhibit increases in relative power during segments with higher mental demands. However, the data from electrode FC2 was needed to detect the higher workload levels brought on by takeoffs, HS ILS tracking, and landing, for example. From the current data, it appears that the segments with the highest cognitive demand produce a topographical spread of alpha band power decrease or delta band power increase when compared with that found during the lower workload levels.

The discrepancies between the heart rate and subjective rating data suggest that the mechanisms underlying these responses are different. The subjective data show that the VFR segments prior to the touch and go are all rated fairly low on the workload scale. The VFR touch and go rating is in the same range as the IFR segment ratings, whereas the two IFR tracking segments are rated as the most difficult of the entire flight. One explanation for these results is that flying familiar maneuvers produces low workload estimates, whereas flying less familiar maneuvers is associated with higher ratings. The more difficult maneuver of the less familiar segments—IFR tracking—produced the highest ratings. The heart rate results may be more sensitive to the actual demands placed on the pilots by each segment. The VFR segment heart rates were consistently lower than those during the IFR segments. Peaks in heart rate were seen during the takeoffs and landings, including the missed approach for both IFR and VFR flying. For the most part, the blink rates decreased during the IFR segments that are associated with the increased visual demands when visual input was restricted to the cockpit instruments. This pattern varied from that found in the subjective results. The reduced blink rate during IFR flight has a counterpart with an increase of rated workload, but the patterns differ. These results demonstrate the value added by the psychophysiological measures. Heart rate, blinks, and EEG provide very useful additional information beyond that available from subjective measures alone. This permits a much more meaningful examination of the effects of flight on pilots. Each of the psychophysiological measures provides unique information. However, there may be some redundancy due to common underlying nervous system mechanisms as the heart rate and EDA data indicate. Overall, one obtains a much better picture of the effects of piloting when one has psychophysiological data available.

Examination of the actigraph and EMG data does not suggest that they influence the primary measures. The actigraph data produce few statistically significant differences among the segments. In fact, these data exhibit significant increases in activity during three segments that required increased hand and arm activity. They are the preflight checklists, engine start, and the climbout when the foggles were donned. These segments are not associated with high heart rates or high levels of EDA activity. This is consistent with prior studies that have reported very low correlations between actigraph measures of activity and heart rate in nurses and healthy elderly individuals (Goldstein, Shapiro, Chicz-DeMet, & Guthrie, 1999; Shapiro & Goldstein, 1998). The analysis of the leg EMG data does not yield many significant differences attributable to the flight segments. The response function does not resemble that of the EDA data. This is consistent with Helander's (1978) conclusion that EDA preceded leg EMG activity in drivers when braking. It seems that the main effects found with the heart rate and EDA data are not caused by interference by these factors.

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