熟能生巧

飛行員發現有些飛行技巧，特別是認知技能，沒有練習就變差了

歐文 譯

有項新的研究指出，座艙廣泛運用自動化系統造成飛行員失去手動操控認知技能的熟練度，像是未使用地圖顯示器時追蹤飛機座標之能力，儘管其他技能在經過長時間後仍保持相對完整。

這項由美國太空總署Ames研究中心Stephen M. Casner所主持之研究發現，飛行員儀器掃瞄技能及手動操控技術仍然很強，即使飛行員說他們並非經常練習。

Casner及其研究團隊所獲致之結論係依據16位飛行員在波音747-400模擬機上執行例行及非例行飛行場景所得結果。

在同一模擬機飛行期間所執行之一項伴隨研究發現，雖然座艙自動化系統之目的是給飛行員更多時間思考與計畫後續航段之飛行工作，然而，在平靜時期，他們心思有時候會到處遊蕩。

這項刊登於2014年12月份人為因素期刊上之新研究報告指出，1971年刊出之一項研究報告表示飛行員在記憶不同類別之技能有不同程度之成效。

2014年的報告表示:「研究人員發現當【像是用於掃瞄儀表及操縱飛行控制之手眼技能】在開始時學的很好，它們就非常不容易忘記，即使有四個月沒有活動。研究中另一類別技巧，也就是認知技能，必須要回想程序步驟，追蹤那些步驟已完成及那些還沒有，想像飛機座標方位，進行心算及發現不正常狀況。如同以前之研究人員，該團隊發現四個月無活動後，飛行員的認知技能已嚴重退化。」

新的報告表示，1971年的研究發現已於當時被負責設定飛行員最低近期經驗要求之管理單位人員作為指導材料。

報告表示:「這項早期研究所提供之智慧在現在的規定中很明顯看的出來。飛行員可在兩年不飛行情況下仍能執行目視規則飛行(機上無乘客)。如果他要在更多認知上要求之儀器飛行規則下行使操作權限，則六個月無活動是上限。」

另外報告表示，目前有關飛行員技能變弱之關切主要起因於座艙自動化作業程度增加並幫忙完成所有工作所造

成之無活動狀態，這些工作包括從進行油料計算與追蹤飛機座標以重設導航裝備，及監控與確認儀表系統失效等。

然而，座艙程序已保留預防飛行員因欠缺運用導致手動飛行技術變弱之方法，也就是透過密切監控自動系統執行之工作並偶而關閉這些系統以達到練習手動飛行技能之目的。

為確定這些方法協助飛行員維持手動技能之效果，研究人員要求為美國航空公司工作之7位正駕駛及9位副駕駛參與這項747-400模擬機研究。這些飛行員平均飛行時數為17,844小時，其中包括在模擬機評估前12個月平均623小時及前一週13小時。參與飛行員表示他們在配備飛行管理電腦(FMC)之飛機上累積了73%的總飛行時數及配備飛航導引儀之飛機上累積89%之總時數。

手眼技能

為使研究人員得以評估飛行員之手眼技能，包括儀表掃瞄能力及飛機手動操控能力，飛行員在FMC中設定三種自動化組合程式之模擬機執行航線飛行。

自動飛行階段包括自動駕駛、飛航導引儀及自動推力之運用以依循FMC所設定之航線。手動操控階段包括飛航導引儀及自動推力系統之運用，加上手動操控駕駛盤以回應飛航導引儀依FMC設定航線執行飛行之指令。在原始資

料及手動操控階段時，飛行員透過操縱駕駛盤，控制推力大小，及依賴主要儀表資訊以追循相同航線。

報告說:「我們要求每位飛行員在三種自動化條件下進行三個階段之飛行(如到場、進場及迷失進場)。為了節省時間，我們並未要求飛行員用自動駕駛進行三個飛行階段，因為我們並未期待使用自動駕駛時飛行員在三個飛行階段會有太大差異。」

研究人員根據飛行員在航線中遵守航道、高度及速度之配當能力打分數。

根據報告指出，在研究調查之反應中，參與飛行員表示他們在基本儀器飛行有很強背景，近期偶而有無自動駕駛之飛行經驗，但近期有同時關掉自動駕駛及飛航導引儀之經驗則非常少。」

表1顯示飛行員在三個不同自動化條件及三個飛行階段之表現，也就是有幾次發生嚴重偏離速度、高度或航道之情況。

研究人員就結果之分析顯示，在到場及進場階段中，自動化條件或有無近期練習對飛行員表現並無重要關聯。在迷失進場階段中，研究人員發現，相較於原始資料及手動操控條件，在手動操控條件下發生速度偏離情況之可能性更高。飛行員之掃瞄及手動操控技能在高壓力飛行階段似乎更可能應接不暇。

結果支持先前研究之發現，亦即只要飛行員正式接受過儀器掃瞄及手動操控訓練，這些技能即使缺少定期練習，也能合理的有效維持。然而，該研究指出結果也顯示:「這些技能的些許萎縮或許需要更多的練習。」

認知技能

參與飛行員一致地向研究人員表示，雖然他們在傳統導航方式有堅強背景，但他們近期並無練習經驗。

表2顯示，飛行員在沒有使用FMC情況下，進到場、進場及迷失進場時的8項導航工作表現，亦即他們在多少次當中至少犯下一次操作上之重大錯誤。就這部分之研究，研究人員比較每位飛行員在運用模擬機之FMC與傳統VHF多向導航台(VOR)之表現差異。

報告表示:「除了需要不同操作程序外，兩種導航裝備在飛行員所需介入程度上也有很大差異。VOR需要飛行員密切追蹤飛行進度，並在飛機抵達每個導航點時重新設定裝備，而FMC則允許飛行員在離場前設定整個航路，並把導航過程想成是一次搞定的設定練習。」

過程包括三項特定未公告儀表系統失效，以測試飛行員是否能夠經由交互檢查儀表發現與確認儀表不正常指示之能力。失效情況包括參與飛行員之航向指示器及高度表，雖然座艙中其他航向指示器與高度表持續運作，而空速靜態系統之阻斷則造成座艙中所有空速指示器失效。引擎指示與組員警告系統也失能。

表2顯示所有飛行員均能把空速控制在允許限度內，而且除一位外，其餘均能夠對到多向導航台並選定入境航道。此外，僅一位飛行員無法進行VOR導航。但6位飛行員未能在迷失進場時依公告航道進行飛行，及7位在迷失進場點時不正確地宣告到場。只有一位飛行員毫無錯誤情況完成整個過程。

報告表示:「總體而言，飛行員報告說，如同儀器掃瞄技能一樣，一旦在初始時精通導航技能，以後就很少會再練習。」但與不容易忘記的儀表掃瞄技能不一樣的是，導航技能已被座艙自動化所取代而變的很容易忘記，很可能需要經常練習以維持高超技能。

在分析飛行員對三項儀表系統失效情況中，研究指出81%參與者向研究人員表示，他們接受相當訓練並練習發現與處理儀表指示不清情況。然而不及一半的參與者表示航空公司熟訓課程中包括了類似練習。

表3顯示，在每項儀表系統失效情況中，包括高度表遲滯、航向指示器歪斜、及空速表不可靠，除了一位外，所有飛行員均說出問題。

在處理高度表遲滯及航向指示器歪斜情況時，較少飛行員正確地採取下一步驟，也就是交互檢查儀表。在空速表不可靠情況中，僅有一位飛行員未能以「明顯企圖」去檢查其他儀表。

在三個場景中的高度表遲滯及空速表不可靠等兩個情況中，大部分飛行員偏離指定高度，而且未能預防進場失速。他們在處理航向指示器歪斜情況時表現較佳，38%偏離指定航向。

報告表示，航向指示器歪斜是三個問題中最容易診斷出來，並指出僅一位飛行員未能診斷出來。另外，報告也表示，81%成功診斷出高度表遲滯情況，56%正確地確認出航向指示器歪斜情況。

資料顯示，那些表示在熟訓訓練中偶而練習處理儀表指示不清楚的飛行員，事實上在三種儀表失效場景中表現並未優於其他人。報告表示有一種可能解釋是熟訓主要著重於幾項相似之失效情況，並未包括處理其他不正常情況之通用方法。

報告表示:「總的來說，資料顯示飛行員在偵測失效時表現良好，但常忽略交互檢查其他儀表，以診斷問題及避免無解失效之後果。有關飛行員接受初期及近期練習後處理儀表指示不清情況之頻率，我們發現認為這類技能容易忘記，但也可在初期及熟訓中多重視而獲益。」

表1

1飛行員於三種自動化條件下之飛行表現(儀表掃瞄及手動控制技能)

自動化條件			
飛行階段	自動飛行	手動控制	原始資料及手動控制
到場			
航道偏離(每員三項航道指定作業)	0%(0/48)	0%(0/48)	2%(1/48)
速度偏離>10kt(每員三項速度指定作業)	8%(4/48)(M=17kt)	23%(11/48)(M=15kt)	15%(7/48)(M=42kt)
高度偏離>300ft(每員三項高度指定作業)	2%(1/48)(M=740ft)	10%(5/48)(M=968ft)	10%(5/48)(M=732ft)
進場			
偏離定位(每員一項定位指定作業)		0%(0/16)	6%(1/16)
偏離下滑道(每員一次下滑道指定作業)		0%(0/16)	13%(2/16)
速度偏離>10kt(每員三項速度指定作業)		0%(0/48)	6%(3/48)(M=21kt)
高度偏離>300ft(每員三項高度指定作業)		0%(0/48)	0%(0/48)
迷失進場			
航道偏離(每員一項航道指定作業)		6%(1/16)	13%(2/16)
速度偏離>10kt(每員二項速度指定作業)		6%(2/32)	38%(12/32)
高度偏離>300ft(每員一項高度指定作業)		0%(0/16)	6%(1/16)(M=310ft)

M=平均值

注釋：根據16位飛行員於波音747-400模擬機上之動作。空格內之資料代表飛行員在執行指定工作中犯下至少一次嚴重之操作錯誤。

資料來源:請參照原文

表2

飛行員未使用飛行管理電腦時之導航表現

導航工作	偏離
對到VOR(每員一次機會)	6%(1/16)
以VOR導航(每員一次機會)	6%(1/16)
高度偏離>300ft(每員二次機會)	16%(5/32)(M=4,686 ft)
速度偏離>10kt(每員二次機會)	0%(0/32)
最後進場航道(每員一次機會)	25%(4/16)
迷失進場點(每員一次機會)	44%(7/16)
進場最低限制(每員一次機會)	19%(3/16)
迷失進場航向(每員一次機會)	38%(6/16)

M=平均值;VOR=VHF多向導航台

注釋：根據16位飛行員於波音747-400模擬機上之動作

資料來源：請參照原文

表3

飛行員在三種儀表系統失效情況下之表現

系統失效情況及飛行員動作	飛行員比例
高度表遲滯	
說出問題	100%
儀表交互檢查	69%
高度偏離	75%
診斷問題	81%
航向指示器歪斜	
說出問題	94%
儀表交互檢查	63%
航向偏離	38%
診斷問題	56%
空速表不可靠	
說出問題	100%
儀表交互檢查	94%
進場失速(操縱桿振動器啟動次數)	94%(M=4.6, SD=4.0)
診斷問題	94%

M=平均值;SD=標準偏離

注釋:根據16位飛行員於波音747-400模擬機上之動作。百分比代表採取指出動作之飛行員數。

資料來源：請參閱原文。

譯自Aero Safety World March 2015

Use it or Lose it

Without practice, pilots find that some flying skills — especially cognitive skills — grow weak.

LINDA WERFELMAN

Extensive use of automated cockpit systems causes pilots to lose proficiency in some cognitive skills required for manually flying an airplane — such as keeping track of aircraft position without using a map display — although other skills remain relatively intact over a long period of time, a new study says.

The study, led by Stephen M. Casner of the U.S. National Aeronautics and Space Administration (NASA) Ames Research Center, found that pilots' instrument scanning skills and manual control skills remained strong, even among pilots who said they practiced them infrequently.

Casner and his research team based their conclusions on results obtained when 16 airline pilots flew routine and nonroutine flight scenarios in a Boeing 747-400 simulator. The researchers varied the level of automation in use, graded the pilots' performance and asked questions about their thoughts during the simulator sessions.

A companion study, conducted during the same simulator sessions (ASW, 7-8/14, p. 26), found that, although cockpit automation systems were designed to give pilots more time to think about and plan for upcoming portions of the flight, instead, during uneventful periods, their minds sometimes wandered.

The report on the new study, published in the December 2014 issue of Human Factors, noted that a research report published in 1971 said that pilots had varying degrees of success in remembering different types of skills.

"The researchers found that when [hand-eye skills such as those used to scan instruments and manipulate flight controls] were initially well learned, they were surprisingly resistant to forgetting, even after four months of inactivity," the 2014 report said. "Another type of skill considered in the study is the set of cognitive skills needed to recall procedural steps, keep track of which steps have been completed and which steps remain,

visualize the position of the aircraft, perform mental calculations and recognize abnormal situations. Like researchers before them, [this team] found that after four months of inactivity, pilots' cognitive skills had significantly deteriorated."

The 1971 research was used at the time as guidance for regulators responsible for setting minimum recent experience requirements for pilots, the new report said.

"The wisdom provided by this early research is evident in the regulations we have today," the report said. "Pilots can wait almost two years without flying and still operate under visual flight rules (with no passengers aboard). If they want to exercise the privileges of operating under the more cognitively demanding instrument flight rules, six months of inactivity is the limit."

Today, the report added, concern about deteriorating pilot skills centers on inactivity associated with the increasing use of cockpit automation to do everything from performing fuel calculations and tracking the aircraft's position to reconfiguring navigation equipment and monitoring and identifying instrument system failures.

Nevertheless, cockpit procedures have retained methods intended to prevent a lack of use from leading to a deterioration of pilots' manual flying skills, by closely monitoring the work performed by automated systems and occasionally shutting off those systems to practice manual flying skills.

To determine how effectively these methods help pilots retain their manual skills, the researchers asked seven captains and nine first officers, all of whom worked for U.S. air carriers, to participate in the 747-400 simulator study. The pilots had an average of 17,844 flight hours, including an average of 623 hours in the 12 months before the simulator evaluation and 13 hours during the previous week. Participating pilots said that they had accumulated 73 percent of their total flight hours in airplanes equipped with a flight management computer (FMC) and 89 percent of their time in airplanes with flight directors.

Hand-Eye Skills

To enable the researchers to evaluate the pilots' hand-eye skills — their instrument scanning abilities and

Pilots' Flying Performance (Instrument Scanning and Manual Control Skills) in Three Automation Conditions

	Automation Condition		
Flight Phase	**Autoflight**	**Manual Control**	**Raw Data and Manual Control**
Arrival			
Off course (3 course assignments per pilot)	0% (0 of 48)	0% (0 of 48)	2% (1 of 48)
Speed deviation > 10 kt (3 speed assignments per pilot)	8% (4 of 48) (M = 17 kt)	23% (11 of 48) (M = 15 kt)	15% (7 of 48) (M = 42 kt)
Altitude deviation > 300 ft (3 altitude assignments per pilot)	2% (1 of 48) (M = 740 ft)	10% (5 of 48)(M = 968 ft)	10% (5 of 48) (M = 732 ft)
Approach			
Off localizer (1 localizer assignment per pilot)		0% (0 of 16)	6% (1 of 16)
Off glide slope (1 glide slope assignment per pilot)		0% (0 of 16)	13% (2 of 16)
Speed deviation > 10 kt (3 speed assignments per pilot)		0% (0 of 48)	6% (3 of 48)(M = 21 kt)
Altitude deviation > 300 ft (3 altitude assignments per pilot)		0% (0 of 48)	0% (0 of 48)
Missed Approach			
Off course (1 course assignment per pilot)		6% (1 of 16)	13% (2 of 16)
Speed deviation > 10 kt (2 speed assignments per pilot)		6% (2 of 32)	38% (12 of 32)
Altitude deviation > 300 ft (1 altitude assignment per pilot)		0% (0 of 16)	6% (1 of 16) (M = 310 ft)

M = mean

Note: Based on actions of 16 pilots in a Boeing 747-400 simulator. Data in cells refer to percentage of tasks during which pilots committed at least one operationally significant error.

Source: Casner, Stephen M.; Geven, Richard W.; Recker, Matthias P.; Schooler, Jonathan W. "The Retention of Manual Flying Skills in the Automated Cockpit." *Human Factors* Volume 56 (December 2014): 1506–1516.

Table 1

their manual control of the airplane — the pilots flew routes that had been programmed into the simulator's FMC with three different combinations of automation.

The autoflight phase involved use of the autopilot, flight director and autothrottle to follow the route programmed into the FMC. The manual control phase involved use of the flight director and autothrottle system along with manual manipulation of the control yoke "in response to flight director commands that directed them along the FMC-programmed route," the report said. In the raw data and manual control phase, pilots followed the same route while manipulating the control yoke, controlling thrust levels and relying on primary flight instruments for information.

"We asked each pilot to fly during three phases of flight (i.e., arrival, approach and missed approach) in the three automation conditions," the report said. "To save time, we did not ask pilots to fly all three flight phases using the autopilot, as we did not expect to see much variation in pilots' performance across the three flight phases when the autopilot was used."

Researchers scored the pilots on their ability to comply with course, altitude and speed assignments on the route.

In their responses to a research survey, the participating pilots said that they had "strong background in basic instrument flying, moderate recent experience in flying without an autopilot and very little recent experience flying with both the autopilot and flight director turned off," the report said.

Table 1 (p. 27) shows how pilots performed — and how many times they committed significant. deviations from speed, altitude or course — in the three different automation conditions and three phases of flight.

The researchers' analysis of the results showed that during the arrival and approach phases, there was "no significant association between automation condition or recent practice on pilot performance," the report said. In the missed approach phase, researchers found "a significantly higher likelihood of a speed deviation in the manual control condition when compared to the raw data and manual control condition. … Pilots' scanning and manual control skills seemed to be more likely overwhelmed in the midst of this hightempo phase of flight." The results supported the findings of earlier research that, as long as pilots had been formally trained in instrument scanning and manual control, those skills were "reasonably well-retained, even in the absence of regular practice." Nevertheless, the study said, the results also showed "some atrophy [in those skills] that perhaps merits additional practice."

Cognitive Skills

The participating pilots were unanimous in telling researchers that, although they had strong backgrounds in conventional navigation methods, they had no recent experience in that area.

Table 2 shows how pilots performed on eight navigation tasks — and how many times they committed at least one operationally significant error — while flying an arrival, approach and missed approach without using an FMC. For this portion of the study, researchers compared each pilot's performance while using the simulator's FMC against his or her performance using a conventional VHF omnidirectional radio (VOR) receiver.

"Aside from requiring different procedures to operate them, the two types of navigation equipment differ more strikingly in how much pilot involvement they require," the report said. "Whereas VORs require the pilot to closely follow the progress of the flight and reconfigure the equipment as [the airplane] arrives at each waypoint, the FMC permits the pilot to program the entire route prior to departure and to think of the navigation process as a 'once-and-done' programming exercise."

The process included three specific unannounced instrument system failures as part of the test of pilots' abilities to recognize and confirm an abnormal instrument indication by cross-checking their instruments. The failures involved the participating pilot's heading indicator and altimeter — although heading indicators and altimeters elsewhere in the cockpit continued operating; and blocking the pitot-static system, which caused malfunctions in all airspeed indicators in the cockpit.

Pilots' Performance When Navigating Without the Use of the Flight Management Computer

Navigational Task	Deviations
Tune VOR station (1 opportunity per pilot)	6% (1 of 16)
Navigate to VOR station (1 opportunity per pilot)	6% (1 of 16)
Altitude deviation > 300 ft (2 opportunities per pilot)	16% (5 of 32) (M = 4,686 ft)
Speed deviation > 10 kt (2 opportunities per pilot)	0% (0 of 32)
Final approach course (1 opportunity per pilot)	25% (4 of 16)
Missed approach point (1 opportunity per pilot)	44% (7 of 16)
Approach minimums (1 opportunity per pilot)	19% (3 of 16)
Missed approach heading (1 opportunity per pilot)	38% (6 of 16)

M = mean; VOR = VHF omnidirectional radio
Note: Based on actions of 16 pilots in a Boeing 747-400 simulator.
Source: Casner, Stephen M.; Geven, Richard W.; Recker, Matthias P.; Schooler, Jonathan W. "The Retention of Manual Flying Skills in the Automated Cockpit." Human Factors Volume 56 (December 2014): 1506–1516.

Table 2

Pilots' Performance During Three Instrument System Failure Events

System Failure Event and Pilot Action	Proportion of Pilots
Altimeter lag	
Verbalized problem	100%
Cross-checked instruments	69%
Deviated from altitude	75%
Diagnosed problem	81%
Heading indicator skew	
Verbalized problem	94%
Cross-checked instruments	63%
Deviated from heading	38%
Diagnosed problem	56%
Unreliable airspeed	
Verbalized problem	100%
Cross-checked instruments	94%
Approached stall (number of stick shaker activations)	94% (M = 4.6, SD = 4.0)
Diagnosed problem	94%

M = mean; SD = standard deviation
Note: Based on actions of 16 pilots in a Boeing 747-400 simulator. Percenitages indicate number of pilots who took the indicated action.
Source: Casner, Stephen M.; Geven, Richard W.; Recker, Matthias P.; Schooler, Jonathan W. "The Retention of Manual Flying Skills in the Automated Cockpit." Human Factors Volume 56 (December 2014): 1506–1516.

Table 3

The engine indicating and crew alerting system also was disabled. Table 2 shows that all pilots were able to hold their airspeed within allowable limits and all but one were able to tune a VOR station and select an inbound course; in addition, only one pilot had difficulty navigating to the VOR station. But six pilots failed to fly the published heading on the missed approach, and seven incorrectly announced their arrival at the missed approach point. Only one pilot completed the entire process without errors.

"Overall, like instrument scanning skills, pilots reported that navigation skills, once initially mastered, are seldom, if ever, practiced," the report said.

"But rather unlike instrument scanning skills, which are resistant to forgetting, navigation skills that have been supplanted by the use of cockpit automation are highly susceptible to forgetting and likely require frequent practice to keep them sharp."

In its analysis of the pilots' responses to the three events involving instrument system failure, the study noted that 81 percent of participants told researchers that they had received "considerable training and practice with recognizing and dealing with puzzling instrument indications." However, fewer than half said their airline recurrent training had included similar practice.

Table 3 shows that in each of the instrument system failures — altimeter lag, heading indicator skew and unreliable airspeed — all but one of the pilots verbalized the problem.

In dealing with altimeter lag and heading indicator skew, fewer pilots correctly took the next step — crosschecking instruments. In the case involving unreliable airspeed, only one pilot failed to make "an obvious attempt" to check the other instruments.

In two of the three scenarios — altimeter lag and unreliable airspeed — most of the pilots deviated from the assigned altitude and failed to prevent the approach of a stall, respectively.

They were better at coping with heading indicator skew, with 38 percent deviating from the assigned heading. Heading indicator skew was the easiest of the three problems to diagnose, the report said, noting that only one pilot failed in his diagnosis. Eightyone percent successfully diagnosed the case of altimeter lag, and 56 percent correctly identified the heading indicator skew, the report said.

Data showed that pilots who reported that they had at least occasionally had practice during recurrent training in dealing with puzzling instrument indications performed no better than the others in the three instrument failure scenarios. The report said that one explanation might be that the recurrent training focused on "a few familiar failures" and did not include general methods of handling other types of abnormal events.

"Overall," the report said, "the data suggest that pilots performed well at detecting failures but often neglected to cross-check other instruments, diagnose the problem and avoid the consequences of an unresolved failure.

In regard to the reported frequency at which pilots receive initial and recent practice in dealing with puzzling instrument indications, our findings suggest that this sort of skill is vulnerable to forgetting and could also benefit from more emphasis during initial and recurrent training."

From Aero Safety World March 2015