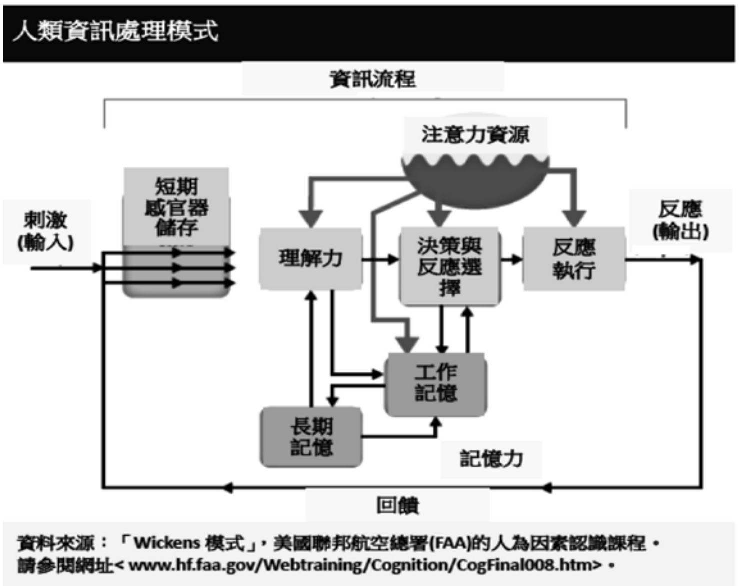
非故意疏失

在許多航空事故中，認知到人類的理解力、注意力、記憶力，以及決策下達等能力的侷限性。

邁德 譯

依據歷史紀錄，大部分飛機發生事故的肇因，都是飛行員的操控疏失(如附註一)；而最不該發生的是，飛行員產生任何心智上的機能失調。事實上，美國民用航空器在最近10年間所發生的2,758件致命事故中，只有少於0.3%的肇因是自殺所導致，而且全都涉及普通航空業(General Aviation, GA)的飛航，而不是商業航空公司的營運航班(如附註二)。取而代之的是，大多數的事故肇因是飛航組員的「非故意疏失」(Inadvertent errors)所造成 — 疏失的發生係來自於正常生理與心理的侷限性，這是人類與生俱來的狀況。本文將檢視這些操作效能的限制並提出建議策略，以協助飛行員減少他(她)們在駕駛艙所遭受到的影響。

從瞭解人類思想的角度來研究人為疏失，這是認知心理學的主要領域。使用電腦當作一個比喻，這種對人類思想與行為的研究方法，係假定由環境輸入(刺激，或是其他資訊)給感官器，而在做出回應(輸出)之前的處理流程。該模式假定資訊處理需要一段時間，正如輸入後從左邊傳到右邊的流程，但也不是人類單純的行為概念，亦即人類只是被動的回應外界刺激；更合理的說，人類通常會積極地去搜尋資訊，隨後才會去處理從左邊傳到右邊的流程。



圖一

世界上研究飛航人為因素的主要專家之一Christopher Wickens，發展出更為複雜的資訊處理模式(如圖一)。人類的資訊處理流程起始於眼睛、耳朵、皮膚，以及前庭等感官器接受到刺激(如表一與附註三)。一般人通常都會認為，某些注意力的機制能夠篩選這些知覺(輸入)，常常會由大腦來察覺或理解而限制這些資訊的類型與數量。這些理解力都會受到以前的經驗(長期記憶)與當時的輸入(短期記憶，或是工作記憶)等的影響。高層次的認知功能，諸如：決策下達和解決問題的能力，也是依賴記憶力，以及接受個人的正確情境感受，或是「情境察覺」(Situational Awareness, SA)等的影響。最重要的是，該模式確認人類的大腦是有侷限的，就像是一部電腦的處理能力，如果輸入超過負載(任務飽和)時，分配注意力的資源給各種心智活動，其有效執行任務的能力，將會顯著地降低。

涉及駕駛飛機的人類主要感官器

人類的知覺	描述：專門的感官器負責發覺特定類型的刺激；重要的是，飛行員能夠獲得外界關於他們的準確資訊。飛行時比較重要的知覺，諸如：視覺、聽覺，而味覺(味道的感覺)通常就比較不重要。
視覺	眼睛是視覺的感官器。每隻眼睛視網膜的光線感受器(桿狀和圓錐細胞)，接受到光線刺激時產生一種化學反應，將光能轉化成神經信號，再通過視覺神經發送給大腦皮層的視覺區。
聽覺	耳朵是聽覺的感官器。位於內耳的耳蝸具有毛狀的聲波感受器，接受到聲波刺激時產生一種神經脈衝，再通過聽覺神經發送給大腦皮層的聽覺區。
觸覺	皮膚是觸覺的感官器。皮膚可以感受到不同類型的壓力、溫度，以及疼痛等觸覺。
嗅覺	鼻腔是嗅覺的感官器。位於鼻腔內的嗅覺感受器，會對各種氣味產生不同的化學反應。特定的感受器負責發覺特定的氣味。
前庭	前庭是平衡感的感官器。位於內耳半規管的感受器，在發生角加速度時，對相鄰薄膜內的移動，分別反應其線性加速度。
軀體的知覺	軀體是身體各部位的整體姿勢與相互間運動的感官器。感受器分佈在人體的皮膚、肌肉與關節上，反應重力加速度以提供身體姿勢與運動的知覺。有時被稱為是運動或姿勢的知覺，更普遍地被戲稱為「短襯褲座姿」(Seat-of-the-pants)的知覺，因為在飛行中的加速度經驗，常常會與重力產生混淆。

表一　　　　資料來源：Dale Wilson教授

認知心理學家經常研究這些個別的流程，但經過實驗證實它們是相互依存的。例如某種干擾(諸如：襟翼不正常)，可能會導致自發性的注意力瓦解，造成飛行員太過於關注襟翼的指示狀況，反而忘記了落地前，必須完成起落架的檢查程序。此外研究也顯示，在模式的上游有任何曲解時(諸如：知覺處理，以及/或是理解力)，將產生下游認知功能的不利影響，諸如：決策下達、反應選擇，以及動作執行等(如表二)。

認知的侷限與相關的事故/意外案例

理解力的疏失
● 視覺上的理解力：2013年11月，一架波音747夢想貨機(Dreamlifter)，預定降落在美國堪薩斯州Wichita市的McConnell空軍基地，卻在無意之間降落在Col. James Jabara機場6,100英呎(1,859公尺)長的跑道，位於原本要降落機場的北方約8海浬(15公里)處。不到兩個月之後，另一架西南航空公司的波音737客機，計畫降落在密蘇里州Branson機場，結果卻錯誤降落在M. Graham Clark市中心機場3,738英呎(1,139公尺)長的跑道，位於原本要降落機場的北方約5海浬(9公里)處。這兩架飛機的飛航組員在「目視氣象狀況」(Visual Meteorological Conditions, VMC)下，執行夜間目視進場程序，他們都以為看到的是正確的機場與跑道(註1)。 ● 聽覺上的理解力：1989年2月，聯邦快遞公司一架波音747貨機墜毀在馬來西亞Kuala Lumpur機場33號跑道前的山坡上，造成機上四位飛航組員全部殉職。當時波音747貨機執行「非定向信標」(Non-Directional beacon, NDB)進場，空中交通管制員的許可是：「下降至2400」(2,400英呎)，飛航組員卻聽錯成：「下降至400」(400英呎)(註2)。

注意力的疏失

- 2011年8月，一架歐洲直升機公司AS350直升機墜毀，造成機上四位飛航組員全部殉職。調查後發現，發動機故障係由於燃油耗盡導致，因而墜毀在美國密蘇里州Mosby的中西部國家航空中心附近。調查確定飛行員錯過檢查低油量狀態的三次機會，有部分原因是他經常在他的手機上發送短信。「自己誘導分心」(A self-induced distraction)，美國「國家運輸安全委員會」(NTSB)的報告指出：「他自己把注意力從他必須確保飛行安全的主要責任中移開。」(註3)。

記憶力的失能

- 2008年12月，一架Hughes 369直升機試圖從一艘漁船上起飛，卻失去控制墜入索羅門群島西部的海水中，造成一位飛行員殉職。直升機的機工長目擊這件事故，看見飛行員試圖移除尾旋翼的踏板鎖(沒有成功)。他忘了在起飛前，必須移除踏板鎖(註4)。
- 2003年9月，一架Cessna 206客機撞到美國緬因州Greenville區的地障，造成機上所有的三名乘客罹難。可能肇因是飛行員未能把油箱選擇器放在適當的位置，導致在開始爬升時燃油就已經耗盡(註5)。

決策下達的疏失

- 1983年10月，伊利諾航空公司一架Hawker Siddeley 748客機(航班編號701)，從美國伊利諾州Springfield機場起飛後不久，左發電機失去電力。副駕駛錯誤地把右發電機關掉，而且也無法再接上線以繼續供電。該航班對目的地南伊利諾機場執行儀器氣象狀況的夜間進場，當飛航組員對飛機失去控制時墜毀，造成機上十位人員全部罹難。美國國家運輸安全委員會表示：「此次事故的可能肇因之一是，在失去飛機二具發電機的直流電力(DC)之後，機長決定繼續飛往較遠的目的地機場，而不是轉降在起飛地附近的機場。」(註6)。
- 2013年3月，歐洲直升機公司一架AS350直升機，由阿拉斯加公共安全部門執行目視飛航規則的夜間任務，在美國阿拉斯加州的Talkeetna區附近，執行搜索與救援的任務中撞到地障，造成機上三位人員全部殉職。當時飛行員並未保持儀器飛行，而在飛入儀器氣象狀況後造成空間迷向。美國國家運輸安全委員會指出事故的可能肇因：「飛行員決定在天氣惡化的條件下，繼續保持目視飛航規則飛行。」(註7)。

註解：

註1：「降落在錯誤的機場」美國國家運輸安全委員會，安全警告(Safety Alert, SA)，編號SA-033，2014年3月。請參閱網址<www.NTSB.gov/safety/safety-alerts/Pages/default.aspx>。

註2：「飛虎航空公司一架B-747貨機，墜毀在馬來西亞Kuala Lumpur Subang國際機場前方約7.5英哩處。」航空安全網路的事故說明，1989年2月19日。請參閱網址<aviation-safety.net/database/record.php?id=19890219-0>。

註3：「2011年8月26日，歐洲直升機公司一架AS350 B2直升機(機號N352LN)，墜毀在密蘇里州Mosby區附近，發動機喪失動力係因燃油用盡。」美國國家運輸安全委員會的飛機事故報告，編號NTSB/AAR-13/02，2013年4月9日。請參閱網址<www.NTSB.gov/investigations/AccidentReports/Pages/AAR1302.aspx>。

註4：「2008年12月28日，一架Hughes 369直升機(機號N104BN)，索羅門群島Honiara西部350英哩。」美國國家運輸安全委員會的飛機事故報告，識別編號WPR09LA069，2009年5月12日。請參閱網址<www.NTSB.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20081230X00408&key=1>。

註5：「2003年9月14日，Cessna U206F客機(機號N755FA)，緬因州Greenville區。」美國國家運輸安全委員會的飛機事故報告，識別編號NYC03FA197，2004 年6月30日。請參閱網址<www.NTSB. gov/_layouts/ntsb.aviation/brief2.aspx?ev_id=20030924X01581&ntsbno=NYC03FA197&akey=1>。

註6：「1983年10月11日，伊利諾航空公司Hawker Siddeley HS 748-2A客機(機號N748LL)，墜毀在伊利諾州Pinckneyville區附近。」美國國家運輸安全委員會的飛機事故報告，編號NTSB/AAR-85/03，1985年3月5日。請參閱網址< huntlibrary.ERAU.edu/collections/aerospace-and-aviation-reports/ntsb/aircraft-accident-reports/index.html>。

註7：「2013年3月30日，歐洲直升機公司AS350 B3直升機(機號N911AA)，由阿拉斯加公共安全部門執行遠端落地後起飛離場，遭遇儀器氣象狀況後墜毀在美國阿拉斯加州Talkeetna區附近。」美國國家運輸安全委員會的飛機事故報告，編號NTSB/AAR-14/03，2014年11月5日。請參閱網址< www.NTSB.gov/investigations/AccidentReports/Pages/AAR1403.aspx>。

表二　　資料來源：Dale Wilson教授

從飛機的事故調查報告獲得案例學習，揭示每一個正常人在不同狀態下的理解力，都有認知上的侷限，諸如：注意力、記憶力，以及決策下達等能力，都扮演著因果的關係。後續提出的案例，特別強調其中的某些侷限。

理解力的疏失

在高能見度的飛行天氣下，飛航組員錯過或誤解了視覺上的必要資訊，以避免在白天發生空中撞機(Midair Collision, MAC)，以及在夜間發生「可控飛行撞地」(Controlled-Flight-Into-Terrain, CFIT)的事故。他(她)們也同樣在聽覺上，未能聽清楚或正確瞭解空中交通控制員的通話訊息。例如有很多意外事件(和某些事故)，來自於管制員的指示，以及/或是飛行員的回覆，在另一架飛機使用類似的呼號時，造成呼號上的混淆後果。

注意力的疏失

誤解往往是選擇性注意力瓦解的原因。飛行員未能注意到正確的訊息，卻注意到錯誤的刺激。可控飛行撞地、失去控制，以及其他致命性的事故，發生的原因係飛行員全神貫注於非必要的事務，或是任務已達到飽和點，以及他(她)們的注意力資源被降低，而不能處理當下的所有任務。

記憶力的失能

成功的飛航效能必須依賴記憶力，但飛行員有時候會忘了過去的資訊(回溯性記憶失能)，或是忘了將來要執行的一項重要性任務(前瞻性記憶失能)。後者的例子，包括在落地前忘了伸放起落架；這種事故的發生相當普遍，已經在飛行員之間流傳一句冷嘲熱諷的格言：「天底下只有兩種飛行員 — 一種是沒有放下起落架就落地，另一種是將來就會發生！」此外，商業航空公司的致命事故係因為飛航組員已經忘了 — 不論是因為分心狀態、工作超負荷，或是兩者皆有 — 必須配置飛機起飛的正確外形。

決策下達的疏失

決策下達是一項極為複雜的心智活動。理解力、注意力，或是記憶力等知覺流程上的任何疏失，都會導致糟糕的決策，但決策下達本身也具有侷限性。例如普通航空業與某些商業航空公司的飛行員，在執行「目視飛航規則」(Visual Flight Rules, VFR)轉入「儀器氣象狀況」(Instrument Meteorological Conditions, IMC)時的飛航決策下達，常常會存有某些偏見。2012年的美國普通航空業，在執行目視飛航規則轉入儀器氣象狀況時所發生的事件，約有95%造成致命事故；而相較於同年商業航空業目視轉儀器所發生的事件，只有少於18%造成致命事故(如附註四)。實例研究與事故調查指出決策的偏見 — 諸如：不會受到傷害、樂觀派的偏執(對決策結果的想像，可能有過於樂觀的趨勢)、能力的偏執(對軀體能力與高超技能具有偏愛)、過度自信，以及逐步升級的偏執(導致接受風險增加的陷阱) — 造成部分飛行員的決策是，在進入儀器氣象狀況時，繼續採用目視飛航規則來飛行(如附註五)。

瞭解人類的認知能力，以及它在飛機事故中所扮演的角色，就能夠做出幾項結論與建議。

首要的是，特定飛航情境下的特殊限制，其所造成的風險會更大。例如在無雲霧的天氣下，進行全黑夜的目視進場落地，這可能會使飛行員增加在視野上產生錯覺的一個經歷(諸如：黑洞效應<Black-hole effect>，在全黑夜時飛機和跑道進場端之間沒有地面燈光所造成的威脅)，此種風險是在進場下滑進入跑道之前，發生可控飛行撞地的事故。分心狀態會誘導注意力和記憶力的失能，也是在確定的飛航階段中，更有可能與更會引起不當後果的肇因。因此，飛航組員必須完全理解這些自然的侷限，以及他(她)們在飛行駕駛艙前，都有可能讓自己遭遇到相關的情境。

此外，飛行員能夠運用有效的策略來克服這些認知上的侷限。例如儘管「看見與避免」(See-and-avoid)的方法，在發現飛航的交通狀況上原本就有侷限性，而實際克服它們的最佳策略是：飛行員能夠運用有效的掃描技術、增加飛機醒目的可見度(諸如：打開落地燈)、確保「雷達迴波器」(Transponder)設置正確、運用「社群情報」(Party-line)的無線電廣播資訊以提升情境察覺能力，以及遵守各種法規而減少發生空中撞機的機會(諸如：遵守缺乏獨創性的飛行駕駛艙規

定)。同樣的，這裡也有一些做法和程序，設計用來協助注意力與記憶力的提升，當執行任務涉及飛機的駕駛時：飛行員能夠運用有效的監控策略、遵守標準作業程序(SOPs)，以及運用策略以有效管理心智負荷與分心狀態。

面對此種情境的同時，航空公司能夠協助飛行員而提供訓練，正式進行風險與疏失管理的作為。大多數的航空公司都承認，飛行員在認知上的侷限是人性的一部分，而且儘管他們盡最大的努力加以排除，但飛行員犯下疏失卻是無法避免的；因此，飛航組員必須接受廣泛的訓練，才能在飛行駕駛艙避免犯下疏失。飛航管理部門可以提供飛行員所需要的工具，進而有效管理發生在飛行駕駛艙的疏失，這比假裝這些疏失都不存在，或是當疏失發生時就懲罰飛行員的作法，要好過千萬倍。

威脅與疏失管理

「威脅與疏失管理」(Threat and Error Management，文後簡稱TEM)是一種降低航空作業風險的研究方法。在「線上作業安全查核」(Line Operations Safety Audit，文後簡稱LOSA)期間，基本上運用訓練有素的觀察員作為進行觀察的工具(如附註六)，飛航管理部門可以運用這一槓桿架構，當成一個訓練工具以協助飛航組員有效地管理飛行駕駛艙的風險 — 包括那些因為人性效能而興起的限制。正如TEM名稱的暗示，基於假設的飛航安全威脅是一直存在的，而且飛行員犯下疏失也是無法避免的。

TEM涉及運用反制手段來進行諸如：預期、檢測、避免，以及/或是減輕飛行員可能面對的威脅，並且發現、捕獲與更正他(她)們所犯下的疏失等。當威脅是一種通常發生的狀況，或是外來事務所造成的影響(諸如：系統故障、危害天氣，以及別人的干擾等)時；疏失則是一種不當的行為(或是缺乏行動)，經由飛航組員的操控而產生(諸如：手動飛行疏失、監控疏失，以及檢查手冊使用不當等)。威脅與疏失的兩者之一，都有可能會導致飛機發生不預期狀態 — 諸如：飛機的不當外形、不穩定性進場，或是飛向更高地形的不預期航道等 — 如果對其中任何一項管理不當，可能就會導致一件事故的發生。

TEM的反制手段是一種行為、程序，或是裝備，設計用來避免或減輕威脅與疏失的發生。不論是否正式確定為TEM的反制手段，航空公司的安全系統已經發展到，包括有效管理飛行駕駛艙風險的最佳實用對策。這些行為被設計用來克服天生的限制，如前所述，在理解力、注意力、記憶力，以及其他的認知流程上，並且包括：

- 遵守標準作業程序；
- 遵守缺乏獨創性的飛行駕駛艙規定；
- 管理工作負荷與分心狀態；
- 監控/交互檢查；
- 習慣性的使用檢查手冊；
- 運用口語呼叫；
- 執行穩定性進場；以及，
- 管理自動化操控。

這些都是「一種尺碼適用於所有體型」(One-size-fits-all)的通用策略，設計用來反制各種不可預見的威脅與疏失。然而，飛航組員還必須使用具有針對性的反制手段以對抗特定的威脅，以及/或是疏失。例如當企圖管理的某項風險，涉及到飛行中接近雷雨區、高海拔地區，或是夜間時段等，特定領域的知識與行為就非常重要。同樣的情境，必須制定特定威脅的反制手段，以避免發生空中撞機、跑道入侵，或是遭遇機體結冰等特殊狀況。

古羅馬哲學家Seneca the Younger，經由觀察發現：「人類是會犯錯誤的」。但是他同時指出：「持續存在(錯誤)是魔鬼。」認同前句話的哲理，進而研究成功的方法來管理飛行駕駛艙的風險；隨後運用有效的最佳實用策略，以避免後句話的哲理會實現。

本文作者Dale Wilson教授，任職於美國華盛頓州Ellensburg的華盛頓中央大學航空系。他教導的課程：飛航組員的生理/心理、風險管理，以及撰寫有關飛航組員的安全事務，包括最近共同撰寫的專書「風險管理：飛行員的最佳策略」。

附註：

附註一：「商業航空事故的人為疏失分析」，運用人為因素分析與分類系統(Human Factors Analysis and Classification System, HFACS)，Wiegmann, Douglas、Shappell, Scott等撰述，美國聯邦航空總署(FAA)報告，編號DOT/FAA/AM-01/3，2001年2月。根據文章描述，民用和軍用飛機的事故，有70-80%的肇因涉及飛航組員的操控疏失。請參閱網址<www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2000s/2001/>。

附註二：「2003-2012年發生在美國的飛機幫助飛行員自殺事故」，Lewis, Russell J.、Forster, Estrella M.、Whinnery, James E.、Webster, Nicholas L. 等撰述，美國聯邦航空總署報告，編號DOT/FAA/AM-14/2，2014年2月。請參閱網址<www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2010s/2014/>。

附註三：專家們認為，人類擁有超過五種的基本感官功能。例如觸覺就有寬廣的類別，可以感受到不同類型的壓力、溫度，以及疼痛等觸覺。

附註四：「2012年普通航空業事故」，第24屆飛機擁有者和飛行員飛行安全研究年會，Joseph T. Nall 報告，2015年。請參閱網址<www.aopa.org/Pilot-Resources/Safety-and-Technique/Accident-Analysis/Joseph-T-Nall-Report>。

附註五：風險管理：飛行員的最佳策略「變動的天氣」(第4章)，Wilson, Dale 與Binnema, Gerald 合著，ASA, Newcastle, Washington, U.S.，2014年。

附註六：「線上作業安全查核(LOSA)」，美國FAA「諮詢通告」(Advisory Circular, AC)，編號AC 120-90，2006年4月27日。請參閱網址<www.FAA.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/22478>。

譯自：Flight Safety Foundation, Aero Safety World, October 2016

Inadvertent Errors

Cognitive limitations in human perception, attention, memory and decision making play a role in many aviation accidents.

DALE WILSON

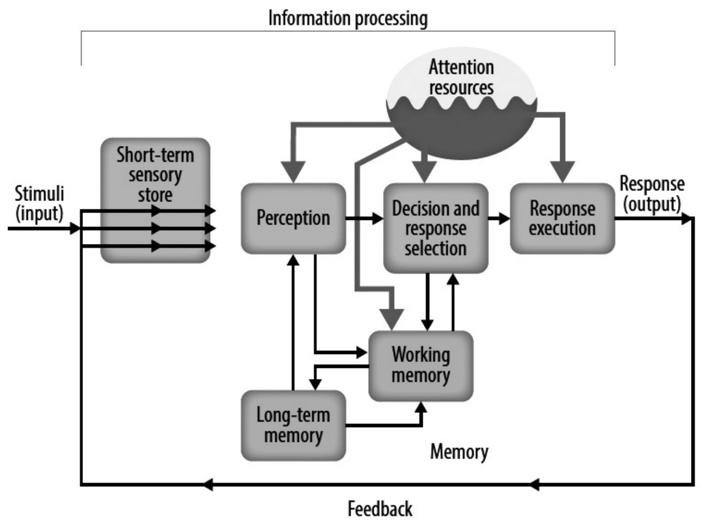
Although the actions of pilots historically have been responsible for the majority of aircraft accidents,[1] most do not arise from any mental disorder. In fact, less than 0.3 percent of 2,758 fatal civil aircraft accidents in the United States during a recent 10-year period were caused by suicide, and all involved general aviation (GA) flights, not commercial airline operations.[2] Instead, most accidents are caused by inadvertent errors made by flight crewmembers — errors that arise from normal physiological and psychological limitations inherent in the human condition. This article examines the role these limitations play in piloting performance and suggests strategies to help pilots minimize their influence on the flight deck.

Understanding human error follows from understanding human thinking, which is primarily the domain of cognitive psychology. Using the computer as a metaphor, this approach to the study of human thought and behavior postulates that inputs (stimuli, or other information) from the environment are received by the senses and are processed before a response (output) is made. The model assumes that information processing takes time as inputs travel from left to right, but also rejects the purely behaviorist notion that humans are merely passive responders to external stimuli; rather, people actively search for information, often processing from right to left.

A more elaborate model, developed by one of the world's foremost researchers in the field of aviation human factors, Christopher Wickens, is found in Figure 1 (p. 26). Information processing begins with stimulation of sensory receptors in the eyes, ears, skin, vestibular apparatus, etc. (Table 1).[3] It is generally agreed that some sort of attentional mechanism filters these sensations (inputs), often limiting the type and amount of information that is perceived, or interpreted, by the brain. These perceptions are influenced by previous experience (long-term memory) and current inputs (short-term memory, or working memory). Higher level cognitive functioning, such as decision making and problem solving, is also memory-dependent and influenced by the accuracy of one's perception of the situation, or "situational awareness." Finally, the model recognizes that the human brain, like a computer, has limited processing capacity, and if overloaded with inputs (task saturation), the attentional resources allocated to the various mental operations needed to effectively perform a task will significantly diminish.

Through experiments, cognitive psychologists often study these processes in isolation but recognize that they are interdependent. For example, a distraction (e.g., a wing flap anomaly) may lead to a breakdown in voluntary attention,

Information Processing Model



Source: U.S. Federal Aviation Administration (FAA). "Wickens' Model." FAA Human Factors Awareness Course. Available at <www.hf.faa.gov/Webtraining/Cognition/CogFinal008.htm>.

Figure 1

causing a pilot to focus too much on the flap indication, which, in turn, could lead to forgetting to accomplish a checklist item such as extending the landing gear before landing. Also, research shows that any distortions upstream in the model (e.g., sensory processing and/or perception) will adversely affect downstream cognitive functions such as decision making and response selection and execution (Table 2, p. 28).

Lessons learned from aircraft accident investigations reveal how otherwise normal everyday human cognitive limitations in perception, attention, memory and decision making play a causal role. The following examples highlight some of these limitations.

Perceptual Errors

In clear flying weather, flight crews have missed or misperceived visual cues necessary to avoid a midair collision (MAC) in the day and controlled flight into terrain (CFIT) at night. They also have failed to detect or correctly perceive vital auditory cues in air traffic control communications. For example, numerous incidents (and some accidents) have resulted from call sign confusion, which occurs when controllers issue, and/or pilots respond to, a clearance intended for another aircraft with a similar call sign.

Attention Failures

Misperceptions are often the result of breakdowns in selective attention. Pilots attend to the wrong stimulus while failing to pay attention to the correct one. CFIT, loss of control and other fatal accidents have occurred because pilots were preoccupied with nonessential tasks, or were saturated with tasks and their diminished attentional resources were unable to cope with all of them.

Forgetting

Successful flight performance is memory- dependent, but pilots sometimes forget past information that they have learned (retrospective memory failure) or forget to execute an important task in the future (prospective memory failure). Examples of the latter include forgetting to extend the landing gear before landing, an event so common that a cynical adage has developed among aviators that says, "There are only two kinds of pilots — those who have landed with the gear up and those who will." In addition, fatal commercial airline accidents have occurred because flight crews have forgotten — whether due to distraction, task overload or both — to properly configure the aircraft for takeoff.

Decision Making

One of the most complex of mental operations is decision making. Any deficiencies in sensory processing, perception, attention or memory can lead to poor decisions, but decision making comes with its own limitations.

For example, biases are often evident in the decision making of GA pilots, and some commercial pilots, who attempt visual flight rules (VFR) flight into instrument meteorological conditions (IMC). Compared with a fatal U.S. GA accident rate of less than 18 percent, some 95 percent of U.S. GA VFR-into-IMC accidents in 2012 resulted in fatalities.[4] Empirical studies and accident investigations indicate that decision biases — such as invulnerability, optimism bias (the tendency to be overly optimistic in envisioning the likely outcome of a decision), and ability bias (a bias that favors the able-bodied and highly skilled), overconfidence and escalation bias (leading to entrapment by acceptance of increasing risks) — have had a part in pilots' decisions to continue VFR flight into IMC.[5]

Major Human Senses Involved in Piloting an Aircraft

Human Sensation	Description Specialized senses detect specific types of stimuli and are important for pilots to obtain accurate information about their external world. Some rank higher when it comes to flying: Vision and hearing are crucial for flight while gustation (sense of taste) usually is not.
Vision	Sense of sight. Photoreceptors (rods and cones) in the retina of each eye are stimulated by light, causing a chemical reaction that converts light energy into neural signals that are sent to the visual cortex via the optic nerve.
Audition	Sense of hearing. Hair-like receptors in the organ of Corti, located in the cochlea of the inner ear, are stimulated by sound waves and create neural impulses that are sent to the auditory cortex via the auditory nerve.
Cutaneous	Sense of touch. Different types of receptors in the skin specifically sense pressure, temperature or pain.
Olfaction	Sense of smell. Olfactory receptors located in the nasal cavity chemically react to a variety of odors. Specific receptors detect specific smells.
Vestibular	Sense of balance. Receptors in the cupula, located in the semicircular canals in the inner ear, move in response to angular acceleration while the membrane located in the adjacent otolith bodies moves in response to linear acceleration.
Somatosensory	Sense of overall position and movement of body parts in relation to each other. Receptors in the body's skin, muscles and joints respond to gravitational acceleration, providing sense of body position and movement. Sometimes called the kinesthetic or postural sensation, it is more commonly referred to as the "seat-of-the-pants" sensation because accelerations experienced in flight can be confused with gravity.

Source: Dale Wilson

Table 1

Several conclusions and recommendations can be made from an understanding of human cognitive performance and its role in aircraft accidents. First, there are specific flight situations in which particular limitations pose a greater risk. For example, conducting a visual landing approach in dark-night conditions in clear weather increases the likelihood of a pilot experiencing a perceptual illusion (e.g., black-hole effect, a threat present on dark nights when there are no ground lights between an aircraft and the runway threshold) with its risk of a CFIT accident short of the runway.

Distraction-induced attention and memory failures are also more likely, and more consequential, during certain phases of flight. Flight crews should, therefore, seek to fully understand the exact nature of these limitations and the context in which they are likely to manifest themselves on the flight deck. In addition, there are effective strategies that pilots can use to overcome these cognitive limitations.

For example, despite the inherent limitations of the "see-and-avoid" method in detecting traffic in flight, best practice strategies exist to overcome them: Pilots can utilize an effective scanning technique; increase aircraft conspicuity (e.g., turn on landing lights); ensure the transponder is correctly set; use party-line radio information to increase situational awareness; and comply with a variety of rules designed to reduce the chance of an MAC (such as maintaining a sterile flight deck). Similarly, there are practices and procedures designed to help improve attention and memory while carrying out the tasks involved in piloting an aircraft: Pilots can use effective monitoring strategies, comply with standard operating procedures (SOPs) and employ strategies to effectively manage mental workload and distractions.

Also, airlines can assist pilots by providing training in formal risk and error-management behaviors. While flight

Accidents/Incidents Related to Cognitive Limitations

Perception Errors

Visual Perception

In November 2013, a Boeing 747 Dreamlifter, destined for McConnell Air Force Base in Wichita, Kansas, U.S., unintentionally landed on a 6,100-ft (1,859-m) runway at Col. James Jabara Airport about 8 nm (15 km) north of McConnell. Less than two months later, a Southwest Airlines Boeing 737, on approach to Branson Airport in Missouri, mistakenly landed on a 3,738-ft (1,139-m) runway at M. Graham Clark Downtown Airport, about 5 nm (9 km) north of Branson. The crews of both aircraft were conducting visual approaches at night in visual meteorological conditions (VMC) and thought they saw the correct airport and runway.[1]

Auditory Perception

In February 1989, a FedEx Boeing 747 crashed into a hillside short of Runway 33 at Kuala Lumpur, Malaysia, killing all four occupants. While the 747 was on a nondirectional beacon (NDB) approach, air traffic control provided the following clearance "descend *two* four zero zero" (2,400 ft), which the crew misinterpreted as "descend *to* four zero zero" (400 ft).[2]

Attention Errors

All four occupants were killed after a Eurocopter AS350 helicopter crashed in August 2011, following an engine failure due to fuel exhaustion near the Midwest National Air Center, in Mosby, Missouri, U.S. The investigation determined that the pilot missed three opportunities to detect the low fuel status, in part because he was frequently texting on his cell phone, a "a self-induced distraction," according to the U.S. National Transportation Safety Board (NTSB) report, "that took his attention away from his primary responsibility to ensure safe flight operations."[3]

Memory Failures

A pilot of a Hughes 369 was killed after loss of control of the helicopter, which struck the water west of the Solomon Islands in December 2008 while attempting to lift off from a fishing vessel. The helicopter mechanic, who witnessed the event, saw the pilot trying to remove the tail rotor pedal lock in flight (unsuccessfully). He had forgotten to remove the lock before takeoff.[4]

All three passengers were killed in September 2003 when a Cessna 206 struck terrain in Greenville, Maine, U.S., and came to rest inverted after the pilot failed to select the fuel selector in the proper position, resulting in fuel starvation during the initial climb.[5]

Decision Errors

Shortly after takeoff from Springfield, Illinois, U.S., in October 1983, Air Illinois Flight 701 lost electrical power from the left generator. The first officer erroneously shut down the right generator and was unable to get it back on line. All 10 occupants were killed after the crew lost control of the Hawker Siddley 748 while approaching their destination of Southern Illinois Airport in night instrument meteorological conditions. The probable cause of the accident was the "captain's decision to continue the flight toward the more distant destination airport after the loss of DC [direct current] electrical power from both airplane generators instead of returning to the nearby departure airport," the NTSB said.[6]

A Eurocopter AS350 helicopter, operated by the Alaska Department of Public Safety under visual flight rules at night, struck terrain while maneuvering during a search and rescue flight near Talkeetna, Alaska, U.S., in March 2013, killing all three occupants. The pilot, who was not current for instrument flying, became disoriented after flying into instrument meteorological conditions. The NTSB said the probable cause of this accident was "the pilot's decision to continue flight under visual flight rules into deteriorating weather conditions."[7]

Notes:

1. NTSB. Safety Alert SA-033, *Landing at the Wrong Airport*. March 2014. Available at <www.NTSB.gov/safety/safety-alerts/Pages/default.aspx>.
2. Aviation Safety Network. Accident Description, *Flying Tiger Line, B-747, 7.5 Miles from Kuala Lumpur Subang International Airport, Malaysia, February 19, 1989.* Available at <aviation-safety.net/database/record.php?id=19890219-0>.
3. NTSB. Aircraft Accident Report NTSB/AAR-13/02, *Crash Following Loss of Engine Power Due to Fuel Exhaustion, Air Methods Corporation Eurocopter AS350 B2, N352LN, near Mosby, Missouri, August 26, 2011*. April 9, 2013. Available at <www.NTSB.gov/investigations/AccidentReports/Pages/AAR1302.aspx>.
4. NTSB. Aircraft Accident Report Identification No. WPR09LA069, *Hughes 369, N104BN, 350 miles west of Honiara, Solomon Islands, 12/28/2008*. May 12, 2009. Available at <www.NTSB.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20081230X00408&key=1>.
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6. NTSB. Aircraft Accident Report NTSB/AAR-85/03, *Air Illinois Hawker Siddley HS 748-2A, N748LL Near Pinckneyville, Illinois, October 11, 1983*. March 5, 1985. Available at <huntlibrary.ERAU.edu/collections/aerospace-and-aviation-reports/ntsb/aircraft-accident-reports/index.html>.
7. NTSB. Aircraft Accident Report NTSB/AAR-14/03, *Crash Following Encounter with Instrument Meteorological Conditions After Departure from Remote Landing Site, Alaska Department of Public Safety, Eurocopter AS350 B3, N911AA, Talkeetna, Alaska, March 30, 2013*. November 5, 2014. Available at <www.NTSB.gov/investigations/AccidentReports/Pages/AAR1403.aspx>.

Source: Dale Wilson

Table 2

crews undergo extensive training to avoid committing errors on the flight deck, most airlines acknowledge that pilots are subject to the cognitive limitations that all humans share, and that despite their best efforts to avoid them, errors made by pilots are inevitable. Rather than pretend these errors don't exist, or punish pilots when the errors occur, flight departments can arm pilots with tools they need to effectively manage error on the flight deck.

Threat and Error Management

One such approach to reducing risk in aviation operations is threat and error management (TEM). Used primarily by trained observers as an observation tool during line operations safety audits (LOSA),[6] flight departments can leverage this framework as a training tool to assist crews in effectively managing risks on the flight deck — including those arising from limitations in human performance. As its name implies, TEM is based on the assumption that threats to safe flight are always present and errors made by pilots are unavoidable.

TEM involves using countermeasures to anticipate, detect, avoid and/ or mitigate the threats pilots may face, and to detect, capture and correct the errors they do make. An error is an improper action (or lack of action) committed by the flight crew (e.g., manual flying errors, monitoring errors and improper use of checklists), while a threat is generally a condition or event outside their influence (e.g., systems malfunction, adverse weather, distractions from others). Either can lead to an undesired aircraft state — such as an improperly configured aircraft, an unstabilized approach or an undesired trajectory toward higher terrain — which, if not properly managed, could lead to an accident.

Countermeasures are behaviors, procedures or devices designed to avoid or mitigate threats and errors. Whether formally identified as TEM countermeasures or not, airline safety systems have evolved to include best practice countermeasures designed to effectively manage risk on the flight deck. These behaviors are designed to overcome the inherent limitations, as noted, in perception, attention, memory and other cognitive processes, and include:

- Adhering to SOPs;
- Complying with sterile flight deck rules;
- Managing workload and distraction;
- Monitoring/cross-checking;
- Habitually using checklists;
- Using verbal callouts;
- Conducting stabilized approaches; and,
- Managing automation.

These are generic one-size-fits-all strategies designed to counter a variety of unforeseen threats and errors. However, flight crews must also use targeted countermeasures to guard against specific threats and/or errors. For example, domain-specific knowledge and behaviors are vital when attempting to manage the risks associated with flying near thunderstorms, at high altitudes or at night. Similarly, threat-specific countermeasures are needed to avoid an MAC, a runway incursion or encounters with airframe icing.

Ancient Roman philosopher Seneca the Younger observed that "to err is human." But he also noted that "to persist [with the error] is of the devil." A successful approach to managing risk on the flight deck acknowledges the former but uses effective best practice strategies to avoid the latter.

Dale Wilson is a professor in the Aviation Department at Central Washington University in Ellensburg, Washington, U.S. He teaches courses in flight crew physiology, psychology and risk management, and writes about flight crew safety matters, including co-authoring the recent book, Managing Risk: Best Practices for Pilots.

Notes

1. Wiegmann, Douglas; Shappell, Scott. U.S. Federal Aviation Administration (FAA) Report DOT/FAA/AM-01/3, A Human Error Analysis of Commercial Aviation Accidents Using the Human Factors Analysis and Classification System (HFACS). February 2001. Available at <www.faa.gov/ data_research/research/ med_humanfacs/ oamtechreports/ 2000s/2001/>. Depending on the sector being described, flight crew error has been implicated in 70 to 80 percent of civilian and military aircraft accidents.
2. Lewis, Russell J.; Forster, Estrella M.; Whinnery, James E.; Webster, Nicholas L. FAA Report DOT/FAA/ AM-14/2, Aircraft-Assisted Pilot Suicides in the United States, 2003-2012. February 2014. Available at <www.faa.gov/data_research/ research/med_humanfacs/oamtechreports/ 2010s/2014/>.
3. Experts believe that humans possess more than the five basic senses. For example, within the broad category of touch, there are separate types of sensory receptors for pressure, temperature and pain.
4. Aircraft Owners and Pilots Association Air Safety Institute. 24th Joseph T. Nall Report: General Aviation Accidents in 2012. 2015. Available at <www.aopa.org/Pilot- Resources/Safety-and-Technique/Accident-Analysis/Joseph-T-Nall-Report>.
5. Wilson, Dale; Binnema, Gerald. “Pushing Weather” (Chapter 4). Managing Risk: Best Practices for Pilots. ASA, Newcastle, Washington, U.S. 2014.
6. FAA. Advisory Circular AC 120-90, Line Operations Safety Audits. April 27, 2006. Available at <www.FAA.gov/ regulations_policies/advisory_circulars/ index.cfm/go/document.information/documentID/ 22478>.

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