Attention, Performance and Cardiac Activity: A Flight Simulator Study

Sylvia Peißl* & Wolfgang Kallus**

* General Psychology / Applied Psychology, Leopold-Franzens-University Innsbruck
** Work, Organizational and Environmental Psychology, Karl-Franzens-University Graz

ABSTRACT
In the field of sports, researchers often distinguish between an internal focus and an external focus of attention. An external focus is when the person concentrates on the distal effects of a movement and appears to be advantageous for motor performance. This is in contrast to an internal focus which occurs when the person focuses on the feeling of a movement. Further, an external focus is associated with a higher heart rate compared to an internal focus. The aim of this paper is to transfer the external-internal focus concept to aviation. In a flight simulator study with 18 participants with generic simulator experience, landing performance and cardiac activity were analysed in relation to attentional focus. It was found that an external focus results in better landing performance and that heart rate significantly increases a few seconds before touchdown. During the phase of approach an internal focus should be avoided as far as possible. In further studies, attention models for pilots including the aspect of time (when to focus) could be developed.

Keywords
Attention processes – aviation – heart rate – flight simulator

1 Introduction

Attention plays an important role in human performance (Munzert & Maurer, 2007). For instance, individuals often have to manage several tasks simultaneously or focus their attention to a special part of a task. Thus, performance depends on many factors including the ability to manage attentional resources successfully (Norman & Bobrow, 1975; Wickens, 1992).

In recent years, many studies have been published indicating that directing a person's attention to body movements respectively to the self (internal focus) hampers motor performance (e.g. Bell & Hardy, 2009; Wulf & Lewthwaite, 2009). In contrast, a focus on the effect of a movement (external focus) has been shown to facilitate motor performance in sports. The advantages of an external focus were observed for sports related activities such as running (Schucker et al., 2009), golf (Bell & Hardy, 2009), skiing in a simulator (Wulf, Höß & Prinz, 1998), soccer, and volleyball (Wulf, McConnel, Gärtner & Schwarz, 2002). Furthermore, an external focus seems advantageous for balance tasks (Wulf, McNevin & Shea, 2001). This finding could be extended to playing a music instrument in front of an audience (Wulf & Lewthwaite, 2009). With regard cardiac activity, an external focus is associated with a lower heart rate compared to an internal focus (Lacey, 1967). An internal focus giving attention primarily to internal thoughts or feelings may not only be inefficient but also dangerous during activities such as driving a car or steering an aircraft. For pilots, this may be especially the case during landing and low-level flight. These two skills rely heavily on visual processing, as the crew have to fly very close to the ground. Crashes during final approach and landing account for 36 percent of all fatal accidents and onboard fatalities in commercial aviation (Boeing Corporation, 2011). Thus, to improve flight safety it is important to pay attention to the visual processing skills of pilots during the final approach and landing (Gibb, Gray & Scharff, 2010).

Finally, performance and attention are very sensitive to physical stressors (e.g. noise) or occupational stressors (e.g. time pressure). Noise, for instance, has been found to lead to an increase in arousal, higher selectivity of attention, a decrease of accuracy, and poorer performance of short-term memory (Semmer & Udris, 2004; Hockey, 1986). Performance does not automatically suffer from physical stressors (Yerkes & Dodson, 1908). Higher selectivity of attention as a consequence of stress can improve the performance of easy tasks (Easterbrook, 1959; Hockey, 1970). Whereas more complex tasks suffer from narrow attention. As flying is a complex task, we assume that high selectivity of attention worsens flight performance. However, noise, leading to higher attentional selectivity, is supposed to worsen flight performance in our study.

In sports there is some indication that focus of attention (as well as performance) is dependent on expertise. With growing expertise attention is more and more goal oriented and anticipatory, less reactive and less activity oriented. Thus we expect large differences for people with only generic flight simulator experience as experienced pilots might well have learned an optimal attentional focus for basic flight maneuvers.

To sum up, the advantages of an external focus of attention have been demonstrated for different forms of motor skills and levels of expertise. As flying an airplane is a complex motor skill, this study transfers the external vs. internal focus concept to flying performance. An external attentional focus should lead to better landing performance with participants showing lower heart rates compared to an internal focus (Lacey, 1967). In addition, the influence of noise and expertise on flight performance is analysed. We assume noise worsens flight performance.

2 Method

Design

We worked with a 2 x 2 design. On the one hand we compared two attention groups: the external focus group and the internal focus group. On the other hand we compared maneuvers with added noise (present) and maneuvers without added noise (absent). The order of the maneuvers was permutated over the participants. Table 1 illustrates the design of the study.

Flight performance was measured by means of two variables: Number of successful approaches and performance approach profile.

For the variable number of successful approaches, successful approaches of each participant were counted. All together four maneuvers had to be mastered, that means the highest success equates to four successfully mastered landings and no crash with the simulator.

The performance approach profile was assessed using the MOBADI approach profile (Motion Based Disorientation project by Kallus & Tropper, 2007 a). Each approach of the participants was rated on a scale between 1 and 3, whereupon the value 1 stood for a bad performance (too low or too steep approach), value 2 indicated a moderate performance and value 3 a good performance (ideal approach angle).

Participants

Eighteen (11 female, seven male) flight novices with flight simulator experience (less than 20 hours) were recruited to take part in the study. All of them had at least 12 years of education. The mean age of the participants was 24.6 years (*SD* = 3.9); none of them was holding a flight licence, 16 participants possessed a driving licence. They were recruited by sending invitations to different Austrian flight academies. Furthermore an advertising poster was placed at the university's „news board“. The participants got to know their performance results after the simulation.

Apparatus and physiological measures

For flight simulation we used an Airfox DISO® flight simulator (AMST Systemtechnik GmbH Ranshofen, Austria) and chose two different maneuvers: Runway width sloped approach and Black hole approach. A sloped runway easily leads to misperception of flying altitude and runway size. Black hole describes the featureless terrain that surrounds the runway and prevents pilots from using objects in the environment to guide an approach.

Table 1: Experimental design and maneuvers, n = 18.

		Noise	
		Absent	**Present**
Attention	External (*n* = 9)	Runway Width Sloped Approach Black Hole Approach	Runway Width Sloped Approach Black Hole Approach
	Internal (*n* = 9)	Runway Width Sloped Approach Black Hole Approach	Runway Width Sloped Approach Black Hole Approach

Noise was manually added at a certain distance to the runway, lasted for 10 seconds and was 80 dB loud.

Physiological stress reactions were assessed by ECG IN FULL-registrations using an amplifier by g.tec, Graz and a MATLAB/Simulink (Mathworks, Inc.) based software system. One relevant phase was considered: approach phase during the maneuver runway width sloped approach. The phase of approach lasted from 20 seconds before touch down till 20 seconds after touch down.

Procedure

The experiment required about 90 minutes. First, the participants were informed about the procedure and ECG electrodes were assigned. Baseline measurements of 120 seconds were collected. In order to ensure that the participants could manage a landing, they had 30 to 60 minutes time to practice at the flight simulator. Afterwards, the participants were randomly assigned to one of two attention groups and were instructed how to focus their attention. The internal focus group was instructed to focus their attention on their movements and feeling of movement („Focus on the feeling of the joystick. Focus on the effects that your movements have on the machine“). The external focus group was supposed to concentrate on instruments and screen. In addition, the external focus group got the instruction on certain speed to tie their attention towards the flight instruments. („Focus on your instruments and on everything outside the machine. Hold a mean speed of 100 knots“).

During the course of the experiment each participant was required to perform four maneuvers:

(a) Runway width sloped approach
(b) Black hole approach
(c) Runway width sloped approach with added noise
(d) Black hole approach with added noise

One approach maneuver needed approximately 20 minutes. Thus, the whole flight simulation including four maneuvers lasted for approximately 80 minutes.

3 Results

Attention and Performance

An objective of this study was to determine whether an external focus of attention led to better flight performance than an internal focus (e.g. Wulf & Lewthwaite, 2009). Independent t-tests for the performance variables were calculated (see Table 2).

Mean differences were found in the measure Number of Successful Approaches, t (16) = -2.97, p = .009, d = 0.6. Figure 1 shows this difference. Flight performance is better for the external focus group. The external focus group performed significantly more successful approaches than the internal focus group. An independent t-test for the dependent variable performance approach profile showed no significant differences between the two attentional focus groups, t (16) = –1.78; p = .095, d = 0.41.

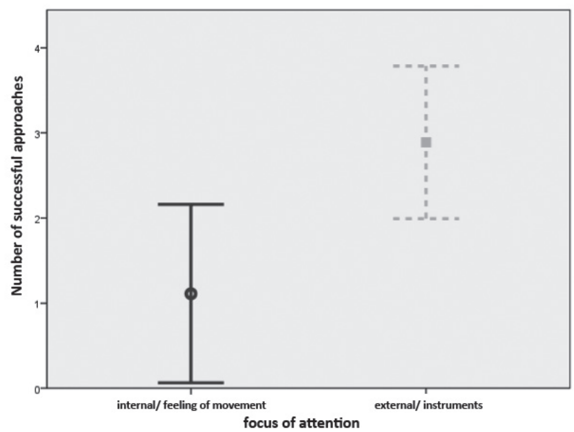

Figure 1: Focus of attention group and landing performance.

Attention and cardiac activity

A further objective of the study was to investigate whether the two attentional focus groups (internal, external) differed in their cardiac activity. Therefore, we analysed heart rate during the approach phase of

Table 2: Performance of the two attention groups.

Attention	Number of successful approaches *(SD)*	Performance approach profile *(SD)*
Internal	1.1 (1.4)	1.4 (0.3)
External	**2.9** **(1.2)**	**1.7** **(0.4)**

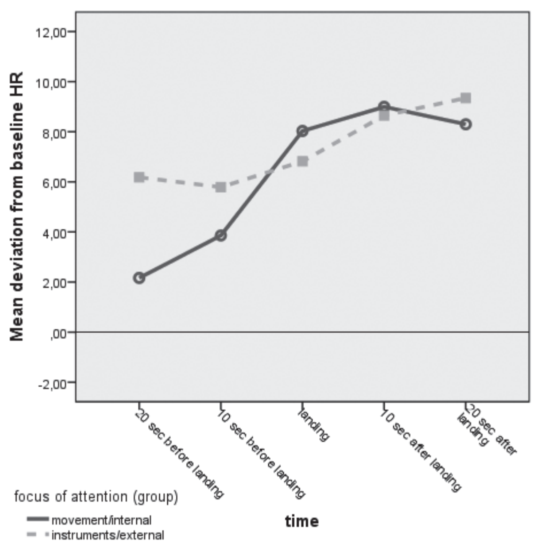

Figure 2: Heart rate for the two attention focus groups during final approach and landing.

the maneuver runway width sloped approach (without noise). We conducted a one-way ANOVA for repeated measures. No group differences and no interaction between performance group and time of measurement could be observed [F (1, 9) = .066, p = .803, η^2 = .007; interaction: F (4, 36) = 1.252, p = .292, η^2 = .091]. Though, significant mean differences for time of measurement were shown, F (4, 36) = 4.18, p = .007, η^2= .32. Post hoc tests revealed a significant increase of heart rate shortly before touch down for both attention groups, t (10) = -2.77, p = .02, d = 0.66.

Performance and Noise

To determine whether the added noise was able to decrease the performance of the participants, we compared each maneuver with and without noise. For the maneuver black hole approach significant differences could be observed in the variable number of successful approaches, t (17) = 2.204, p = .042, d = 0.47. Performance was significantly worse in the noise condition than in the no-noise condition.

For the maneuver runway width sloped approach, performance was neither better nor worse in the noise condition, t (17) = –1, p = .331, d = 0.24.

4 Discussion

Attention and Performance

The results of this study showed that adopting an external focus of attention during final approach and landing leads to better landing performance. Thus, a transfer of the internal-external attention concept from other research areas such as sports and music seems justified. But why does an external focus lead to better performance? An external focus facilitates the automation of motor movements; an internal focus on the contrary results in a more conscious kind of motor control (e.g. Wulf, McNevin & Shea, 2001). This conscious control can hamper the motor system and disable automatic control processes (McNevin, Shea & Wulf, 2003).

Attention and Cardiac Activity

The two focus groups did not differ in their patterns of cardiac activity. At the moment of touch down heart rate increases significantly in the maneuver runway with sloped approach for both groups, which can be explained as an increase of workload or as an indicator of emotional load (Gramann & Schandry, 2009; Wilson, 2002). As the participants were novices the landing certainly was the most demanding task of the flight and so the heart rate was increasing shortly before touch down. Demanding aerobatic maneuvers would probably change the cardiac activity profile and landing would no longer be the maneuver with the highest heart rate (Dahlstrom et al., 2011). The increase of heart rate shortly before touchdown could also be seen as an anticipation effect (Kallus & Tropper, 2007 b).

Performance and Noise

A further objective of the study was to find out whether a physical stressor such as noise can degrade landing performance. Indeed, participants crashed more often in the „noisy“ maneuver black hole approach than in the corresponding maneuver without noise. Whereas in the maneuver runway width sloped approach, noise did not influence performance. According to Hockey (1986) the physical stressor noise leads to higher selectivity of attention. Selective attention does not automatically mean that performance worsens. Wickens (1992) compared attention to the ray of a flashlight. Stress respectively arousal narrows this ray, peripheral information is faded out and concentration is led towards central aspects of a task. For easy tasks, a narrow ray of attention can be beneficial and lead to an improvement of performance as sources of disturbance are faded out (Easterbrook, 1959, cited Kallus, 1982). With an increase of difficulty and arousal, performance worsens. The result of the present study could be explained by Easterbrook’s hypothesis. The runway width sloped approach was the easier maneuver. Noise led to a narrowing of attention, which was beneficial for performance of the easy maneuver. The black hole approach was a more difficult task and performance decreased under the influence of noise.

5 Conclusions

As the attentional focus has been shown to influence flight performance, it may be appropriate for further investigations in this area and to apply the results of attention studies to flight training and selection. For an optimal landing, attention needs to be given to the right things at the right time. An internal focus is not advantageous during the phase of approach and should be avoided as far as possible. In further studies, attention models for pilots including the aspect of time (when to focus) could be developed and tested on expert pilots flying different scenarios. Furthermore the aspect of visualisation (having a picture of relevant elements of air traffic) could be included in attention studies, as it was found the most demanding change in ability requirements for pilots (Eißfeldt, 2011).

The first step in transferring a concept from sports-related research to aviation psychology has been made. Further studies examining expert pilots certainly will follow.

References

Bell, J. J. & Hardy, J. (2009). Effects of Attentional Focus on Skilled Performance in Golf. *Journal of Applied Sport Psychology, 21*, 163-177.

Boeing Corporation (2011). Statistical Summary of Commercial Jet Airplane Accidents. Seattle, WA: Boeing Commercial Airplanes. Retrieved October 12, 2011 from http://www.boeing.com/news/techissues/pdf/statsum.pdf

Dahlstrom, N., Nahlinder, S., Wilson, G. F. & Svensson, E. (2011). Recording of Psychophysiological Data During Aerobatic Training. *The International Journal of Aviation Psychology, 21* (2), 105-122.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66* (3), 183-201.

Eißfeldt, H. (2011). Ability Requirements for Air Traffic Controllers and Pilots in future ATM Systems: Results from the DLR Project Aviator 2030. In K. W. Kallus, M. Heese, P. Knabl & M. Feldhammer (Hrsg.), *Aviation Psychology in Austria 2. Human Factors, Critical Psychological States and Maintenance* (25-37). Wien: Facultas.

Gramann, K. & Schandry, R. (2009). *Psychophysiologie. Körperliche Indikatoren psychischen Geschehens. 4., vollständig überarbeitete Auflage*. Weinheim Basel: Belz.

Gibb, R., Gray, R. & Scharff, L. (2010). *Aviation Visual Perception. Research, Misperception and Mishaps*. Surrey: Ashgate.

Hockey, G. R. J. (1970). The effect of loud noise on attentional selectivity. *Quarterly Journal of Experimental Psychology, 22* (1), 28-36.

Hockey, G. R. J. (1986). A state control theory of adaptation to stress and individual differences in stress management. In G. R. J. Hockey, A. W. K. Gaillard & M. G. H. Coles (eds.), Energetics and Human Information Processing. Dordrecht: Martinus Nijhoff.

Kallus, K. W. (1982). *Entscheidungsprozesse unter Belastung. Experimentelle Untersuchung zur Wirkung und Interaktion unterschiedlicher Belastungsbedingungen in einem psychophysiologischen Untersuchungsansatz*. Unveröffentlichte Dissertation. Universität Düsseldorf.

Kallus, K. W. & Tropper, K. (2007 a). *MOBADI-MOtion BAsed DIsorientation: Perceptual illusions / spatial disorientation training for VFR pilots*. Retrieved October 13, 2011, from http://www.amst.co.at/downloads/r_d_publications/MOBADI_Englisch_20070118.pdf

Kallus, K. W. & Tropper, K. (2007 b). Anticipatory Processes in critical flight situations. In *Proceedings of the 14th International Symposium on Aviation Psychology*, Dayton, Ohio.

Lacey, B. C. (1967). Somatic response patterning and stress: Some revisions of activation theory. In M. H. Appley & R. Trumbull (eds.), *Psychological stress: Issues in research*. New York: Appleton-Century-Crofts.

McNevin, N. H., Shea, C. H. & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research, 67*, 22-29.

Munzert, J. & Maurer, H. (2007). Instruktion, Übung, Feedback – Schlüsselvariablen auf dem Weg zur motorischen Expertise. In N. Hagemannd, M. Tietjens & Strauß, B. (Hrsg.), *Psychologie der sportlichen Höchstleistung. Grundlagen und Anwendungen der Expertiseforschung im Sport* (192-217). Göttingen: Hogrefe.

Norman, D. & Bobrow, D. (1975). On data-limited and resource-limited processing. *Journal of Cognitive Psychology, 7*, 44-60.

Schucker, L., Hagemann, N., Strauss, B. & Volker, K. (2009). The effect of attentional focus on running economy. *Journal of Sports Sciences, 27*, 1241-1248.

Semmer, N. & Udris, I. (2004). Bedeutung und Wirkung von Arbeit. In H. Schuler (Hrsg.), *Lehrbuch Organisationspsychologie* (3., vollständig überarbeitete Aufl.). Bern: Huber.

Wickens, C. D. (1992). *Engineering Psychology and Human Performance*. Second edition. New York: HarperCollins Publishers Inc.

Wilson, G. F. (2002). An analysis of mental workload in pilots during flight using multiple psychophysiological measures. *International Journal of Aviation Psychology, 12* (1), 3-18.

Wulf, G., Höß, M. & Prinz, W. (1998). Instructions for Motor Learning: Differential Effects of Internal Versus External Focus of Attention. *Journal of Motor Behavior, Vol. 30* (2), 169-179.

Wulf, G. & Lewthwaite, R. (2009). *Attentional and Motivational Influences on Motor Performance and Learning*. In A. Mornell (ed.), Art in Motion. Muscial and Athletic Motor Learning and Performance. Peter Lang: Frankfurt am Main.

Wulf, G., McConnel, M., Gärtner, M. & Schwarz, A. (2002). Enhancing the Learning of Sport Skills Through External-Focus Feedback. *Journal of Motor Behavior, 34* (2), 171-182.

Wulf, G., McNevin, N. H. & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology, 54A* (4), 1143-1154.

Yerkes, R. M. & Dodson, J. D. (1908). The Relation of Strength of Stimulus to Rapidity of Habit-Formation. *Journal of Comparative Neurology and Psychology, 18*, 459-482.

Correspondence to:
Mag. Dr. Peißl Sylvia
Leopold-Franzens-University Innsbruck
Institute of Psychology
General Psychology
Innrain 52
A-6020 Innsbruck
sylvia.peissl@uibk.ac.at