

Game-like digital training tools: Transfer of cognitive and perceptual skills from static to dynamic interfaces

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This paper explores the principles of skill acquisition and training transfer within the context of game-like digital training tools, expanding on previous research using an instrument scanning task in novice versus experienced pilots. While previous work demonstrated a game-like training tool is capable of developing high levels of performance within the game environment, initial findings suggest the likelihood of practical transfer to a real world environment is strongly dependent on the nature of the cognitive and perceptual skills developed. This paper investigates whether instrument scanning skills developed within a static training task transfer to a more dynamic video-based task. Despite strong performance within the static environment, preliminary data suggest a lesser degree of transfer when more dynamic perceptual skills are targeted. Findings are discussed broadly in terms of the principles of skill acquisition and training transfer, and how these principles may apply to game-like digital training tools.

Keywords: Training Games, Training Transfer, Skilled Performance, Instrument Scanning,

Introduction

Today's students and trainees grow up in a digital world, in many cases potentially spending as much time interacting with digital technologies and virtual worlds as they do with the real world around them (Gee 2007). Having grown up in this technology rich environment, it has been argued that today's learners may have developed an alternative skill set more tailored to learning within the digital world and this notion has led many researchers and practitioners to consider how to leverage these technologies for educational and training purposes (Gee, 2007). Much of this interest has focused on the use of virtual environments, serious gaming, and game-like digital training tools to build knowledge and skills relevant to the real world.

The variety of game-like technologies currently in use is immense and while some have undergone a variety of evaluations (e.g., Roman & Brown, 2008), others have seen very little if any. In some fields, interest in game-like training tools has resulted in such technologies rushed into service in order to meet the increasing training demands of both students and instructors alike. This has been particularly the case within some military training environments where the pressure to provide trainees with cost effective training tools continues to mount, potentially at the expense of proper training needs analysis and evaluation of training tools, training programs and training outcomes. "Right now, nobody wants to be the control group" (Robert Bowen, Chief of U.S. Army Training and Doctrine Command Capability Manager (TCM-Gaming), cited in Peck 2012; pg 2). Particularly within the military environment, it is critical to establish firstly whether these new training technologies represent effective training environments, but secondly whether the skills developed using digital training tools effectively transfer to real world operational environments and modes of practice. There is also the very real possibility that training with tools based on a games metaphor may lead trainees to develop bad habits or result in instances of negative training transfer, through the types of motivational incentives built in to game-like scenarios.

While the diversity, graphical detail, and ubiquitous nature of game-like training environments have developed considerably in recent years, the underlying principles of skill acquisition and training transfer have not. While game-like digital training tools differ significantly from more traditional training environments, it is still possible to effectively establish their training effectiveness based on the nature of the fundamental cognitive, perceptual, and psychomotor skills developed. This paper uses a relatively low-tech example of a game-like

training tool (based on a tool developed by Kellman & Kaiser, 1994 and further modified by McLean, Wise & Williams, 2011) to investigate these issues and examines aspects of training transfer within a game environment.

Developing Pilot Instrument Scanning Skills - A game-like digital training tool

In 1994, Kellman and Kaiser developed what they termed a perceptual training module designed to promote more efficient information extraction, higher order pattern processing, and levels of automaticity in pilot instrument scanning skills (Kellman & Kaiser, 1994). The task required participants to view a static display of a standard-six aircraft instrument panel and identify the aircraft situation as quickly as possible (e.g., climbing, descending, turning etc). The findings demonstrated dramatic improvements in speed and accuracy after only a brief period of training (approximately 1 hour), both in novice participants and experienced civil aviation pilots. As to be expected, experienced pilots were initially much faster and more accurate than novice participants, yet by the end of the training task, novice participants' accuracy had increased dramatically (performing close to ceiling) and they were exhibiting reaction times significantly faster than those initially demonstrated by experienced pilots (Kellman & Kaiser, 1994). The interpretation of the authors was that this training task was clearly effective in developing instrument scanning skills in novices and improving skills in pilots. In principle, if such high levels of performance (equivalent to those of expert pilots) can be developed so rapidly, then these findings hold significant potential, especially considering that with the technology available today, such training tools could easily be disseminated across personal digital devices such as iPads or Smartphones, technologies that were not available, nor as ubiquitous, when the study was originally conducted.

While at first blush the findings of Kellman and Kaiser (1994) indicate that these game-like tasks have considerable potential for training, there is a missing link between the experimental findings and the realisation of such training potential in real world environments. As highlighted above, it is important to understand the nature of the skills being developed within the training task, and crucially, the likelihood of these skills to be applicable within a practical aviation context. Expert pilots demonstrate superior performance compared with novices when initially completing the task, which suggests that their expertise is at least of some relevance, yet the complex cockpit environment (and their extensive experience of this environment) has been significantly condensed in the simple representation provided by the game-like training tool. For example, novice participants may have merely developed a basic perceptual understanding of the relationship between instruments, without the necessary cognitive knowledge of each instrument's meaning or how it relates to other instruments in the panel. Conversely, participants may have developed a basic cognitive understanding of how different instruments interact, but no perceptual concept of how these instruments behave in a dynamic environment. Without understanding these differences, it is difficult to make an educated judgment as to whether the skills developed will prove to be in any way practical in a more realistic scenario.

The Current Study

The current study expands on the recent work of McLean, Wise and Williams (2011) who replicated the original Kellman and Kaiser (1994) instrument scanning training task in a sample of undergraduate psychology students. The findings from this research again revealed that non-pilot participants, most of whom had no intrinsic interest in aviation tasks, were capable of rapidly developing instrument scanning skills in this game-like environment demonstrating dramatic gains in reaction time and accuracy (McLean et al., 2011). This study furthered the findings of Kellman and Kaiser (1994) however by adding an important transfer condition to the original experimental design. While participants were initially trained using a stylized instrument panel as in the original Kellman & Kaiser study (see Figure 1, lower-left and lower-middle panels) performance was later examined on an identical task, except that the stylized instruments were replaced by a more realistic instrument images (Figure 1, lower-right panel) developed from flight simulator imagery (X-Plane Flight Simulator software). Interestingly, while participants were relatively successful in this transfer condition, reductions were still evident in both accuracy and response time compared with performance on the stylized instruments they first encountered in training. That is, despite completing an identical task in two highly similar environments, training transfer was not absolute. A plausible explanation is that, while participants had developed an adequate understanding of the cognitive association between the instruments, a significant portion of their skills was invested in the perceptual representation of the instrument panel and when this perceptual representation was manipulated, albeit only superficially, there was a significant impact on performance. The susceptibility of training transfer to superficial changes in the perceptual rendering of the instrument panel is particularly troubling in the context of the design of the static stimuli used in Kellman and Kaiser task. In order to interpret an aircraft situation from a static instrument display, the motion of some instruments (for example, the rotation of the altitude indicator during a climb) was represented symbolically by use of arrows (see Figure 1). The symbolic representation of direction of motion did not include any indication of the rate of motion or the degree

of displacement generated by different instruments as a function of aircraft situation.

This paper seeks to explore the nature of the cognitive and perceptual skills developed within a game-like training task by further testing the robustness of these skills to perceptual manipulations, specifically, by examining the degree to which these skills transfer from a static environment (either stylized or realistic) to a more dynamic one involving real motion of aircraft instruments. By exploring performance on a similar task utilizing actual instrument motion rather than symbolic representations, significantly more demands are placed on the cognitive representations and perceptual skills developed within the static instrument training task. If the degree of training transfer remains strong within this dynamic setting, it suggests that the cognitive skills developed within the static training task are sufficiently tractable to be of use in more realistic environments. Conversely, if a reduction in training transfer is evident this may indicate that the development of adequate cognitive skills may be of little use, if the real-world perceptual cues remain indecipherable. Such a finding may have important implications for the way in which training tasks using digital technologies and virtual environments are developed for real-world operational tasks, not only in aviation, but also in a range of other skilled domains.

Method

Participants

Participants consisted of a convenience sample of three novice participants and three experienced pilots, with additional data collection in progress. Novices were aged between 26 and 33 and had no aviation experience. Those participants classified as experienced pilots were aged between 28 and 34 and had logged between 52 and 250 hours of flying experience. Participant performance will also be compared with the sample of 87 non-pilot Psychology undergraduates who performed a similar training task as part of the original McLean et al. (2011) study.

Materials

The experiment consisted of two separate instrument scanning tasks; a static instrument scanning (SIS) training task based on the task used by McLean et al. (2011), and an Instrument Failure Video (IFV) task.

Static Instrument Scanning (SIS) Task

The stimuli and procedure used in the SIS task comprised the same standard six instrument panel (Figure 1, top-left panel) utilised by McLean et al. (2011). These instruments consisted of the Airspeed Indicator, Attitude Indicator, Altitude Indicator, Turn Coordinator, Heading Indicator, and the Vertical Speed Indicator. Prior to commencing the experimental phase of the task, each participant was given a detailed explanation of each instrument and how to interpret them in combination. As in Kellman and Kaiser's (1994) task, in each trial the participant was presented with a panel of six instruments, with the objective to determine the aircraft 'situation' as quickly as possible – i.e., "Straight and Level", "Level Left Turn", "Level Right Turn", "Level Climb", "Level Descent", "Climbing Left Turn", "Climbing Right Turn", "Descending Left Turn", or "Descending Right Turn". An additional aircraft 'situation' was also represented where the instrument panel displays "Incongruent" information. For example, as shown in Figure 1 (lower-middle panel), five of the six instruments display a level climb, yet the altitude indicator is incongruent suggesting a descending aircraft. Participants first completed a short series of 10 practice trials before completing 3 blocks of 30 trials utilizing the stylized instrument panel (a total of 100 trials). Following these blocks, participants then completed a transfer condition block (30 trials) in which performance was evaluated on an identical task utilizing a set of stimuli generated using more realistic instrument images (Figure 1, lower-right panel). See McLean et al. (2011) for further details.

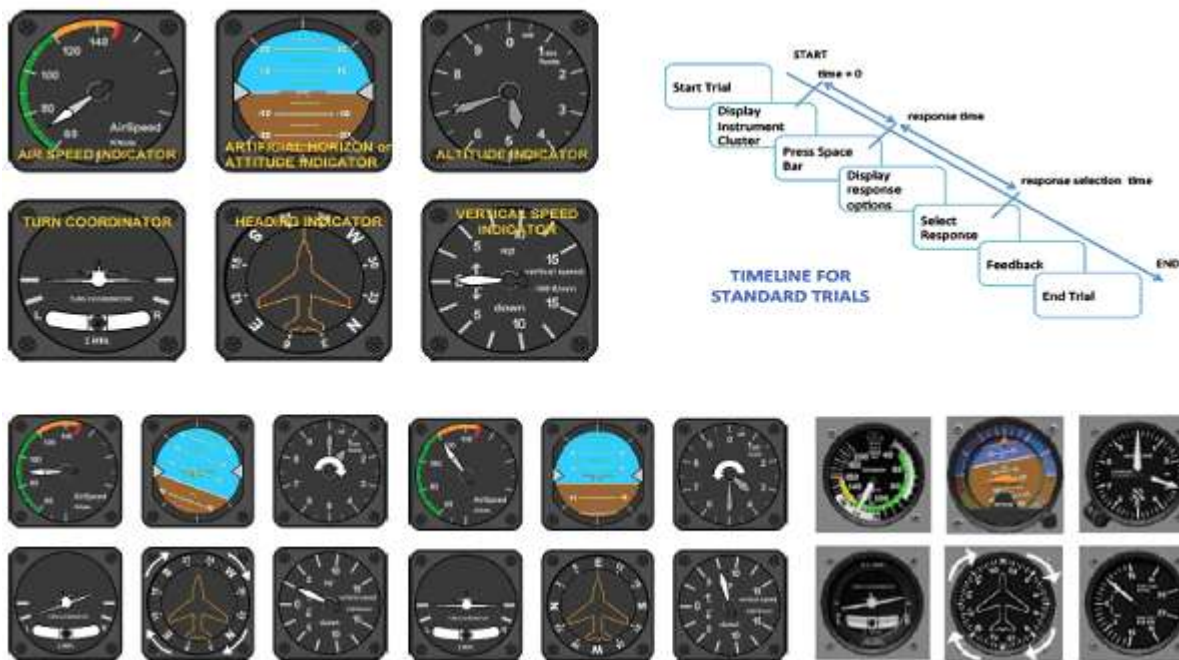


Figure 1: Experimental stimuli. Top-left panel shows the six main instruments of a Cessna cockpit as stylized static stimuli. The top-right panel shows the timeline of stimulus presentation for each trial within a standard trial block. While the top-left panel is congruent with a straight and level aircraft situation, the lower left panel is compatible with a climbing left turn. The middle lower panel conversely shows an “Incongruent” display, with most instruments compatible with a level climb, yet the altitude indicator suggests a descending situation. The rightmost lower panel shows the transfer condition using a more realistic instrument display.

Instrument Failure Video (IFV) Task

In the IFV task, participants viewed 32 short 30-second videos of flight simulation footage captured using flight simulation software (Laminar Research, X-Plane – see Figure 2 for a screenshot). Each segment would start with the aircraft flying straight and level, before executing one of the maneuvers depicted in the SIS task (e.g., “Climbing Left Turn”, “Descending Right Turn” etc), and then finally returning to straight and level flight. In half of the video segments, at the 10, 15, or 20 second mark, one of the instruments would ‘fail’ (i.e. pause) and hence cease to be congruent with the other instruments (akin to the “Incongruent” aircraft situation in the SIS task). The participant’s objective was to observe the video and determine whether any instrument had failed, and identify that instrument as quickly as possible by clicking on the instrument with the mouse.



Figure 2: Example of a screenshot from the IFV task showing the aircraft flying straight and level. In this example, the Turn Coordinator (highlighted in red) has failed indicating a left turn while the remaining instruments suggest straight and level flight.

Procedure

After receiving a series of instructional slides explaining the nature of the task and the instrument panel, participants first completed the IFV task. Following the completion of the IFV task, participants were given a further series of instructional slides before completing the SIS training task inclusive of both the stylized and realistic instrument panel (i.e. transfer condition) trial blocks. Once participants had completed the SIS training task, participants repeated the IFV task with pre and post SIS training performance evaluated across both the experienced and novice pilot participant groups.

Results & Discussion

As shown in Figure 3, initial analyses examined the accuracy and reaction time of novice versus experienced pilots on the SIS task. Consistent with the findings of Kellman and Kaiser (1994), experienced pilots had an initial advantage in accuracy and response time, but non-pilots became as fast, although not quite as accurate as pilots after only 90 minutes of training. Performance of non-pilot undergraduate psychology students from the original McLean et al. (2011) study is also shown in Figure 3 to provide context from a larger sample of participants. It should be noted that differences in performance between the novices from the current study and the undergraduate psychology students from the McLean et al. (2011) study are potentially due to differences in experimental procedure with the undergraduate psychology students completing the study via online delivery (i.e. unsupervised), while the novices in the current study participated in a supervised laboratory environment with substantially fewer trials per SIS block. Furthermore, the small sample size and fewer trials per block may account for the high level of variability in the novice and experienced pilot sample.

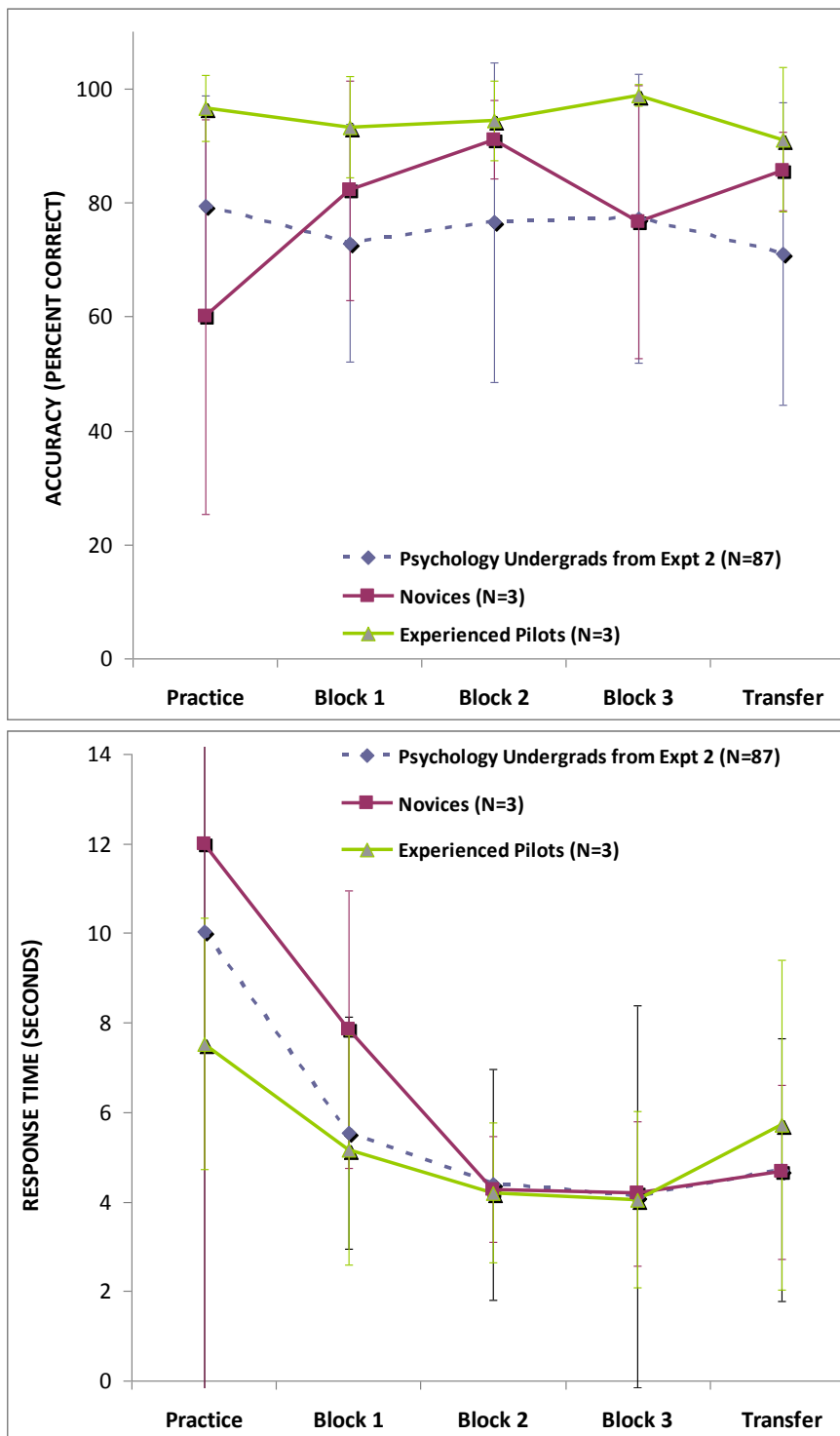


Figure 3: Accuracy and Response Time data for Pilots, Novices, and psychology undergraduate students on the static instrument scanning task (Error bars represent Standard Deviation). See text for further description.

In relation to performance on the transfer block, similar to previous findings discussed by McLean et al. (2011), there was a small reduction in accuracy on the realistic SIS transfer block for experienced pilots, although this trend did not occur for novices in the current study and did not reach significance for either sample. In terms of response time in the transfer block, while participants exhibited faster responses compared to their initial attempts at the stylized SIS task, all participants in both the novice and experienced pilot groups exhibited slower response times compared to the final training block of the stylized SIS task. As discussed above, while

there was substantial training transfer between the stylized and realistic SIS conditions, transfer was certainly not absolute.

In regards to performance on the IFV task, Figure 4 highlights performance on the task both pre and post SIS training. Similar to the pattern of performance evident on the SIS training task, when first completing the IFV task the experienced pilots exhibited superior accuracy compared with novices. That experienced pilots exhibit superior performance on this IFV task prior to SIS training suggests that the task has considerable ecological validity and is tapping into significant aspects of the pilots' aviation experience. Experienced pilots proved capable of identifying the majority of instrument failures (in fact two pilots performed at close to ceiling – above 90% accuracy). Conversely, novice participants identified approximately half of the instrument failures correctly, that is, they performed at close to chance.

In regards to post SIS training performance on the IFV task, experienced pilots exhibited little gains in accuracy (83%) compared to pre SIS training performance although this could largely be expected given the pilots had initially exhibited a relatively high level of performance pre SIS training (76%). Of more theoretical relevance however, was how novice participants performed on the IFV task pre and post SIS training, with these findings of particular interest in that they can be interpreted in two different ways. On the one hand, a substantial degree of training transfer is evident with performance on the IFV task higher post-training (67%) compared to performance pre-training (47%). Conversely however, accuracy on the IFV task post-training was still only slightly higher than chance (50%) and considerably lower than on any of the stylized (post training – as high as 91%) or realistic SIS training conditions (86%), suggesting a significant portion of the skills gained during the SIS training did not effectively transfer to a more dynamic environment. Indeed a proportion of the gains that are evident on the IFV task could be attributable to practice effects resulting from completing the task pre SIS training.

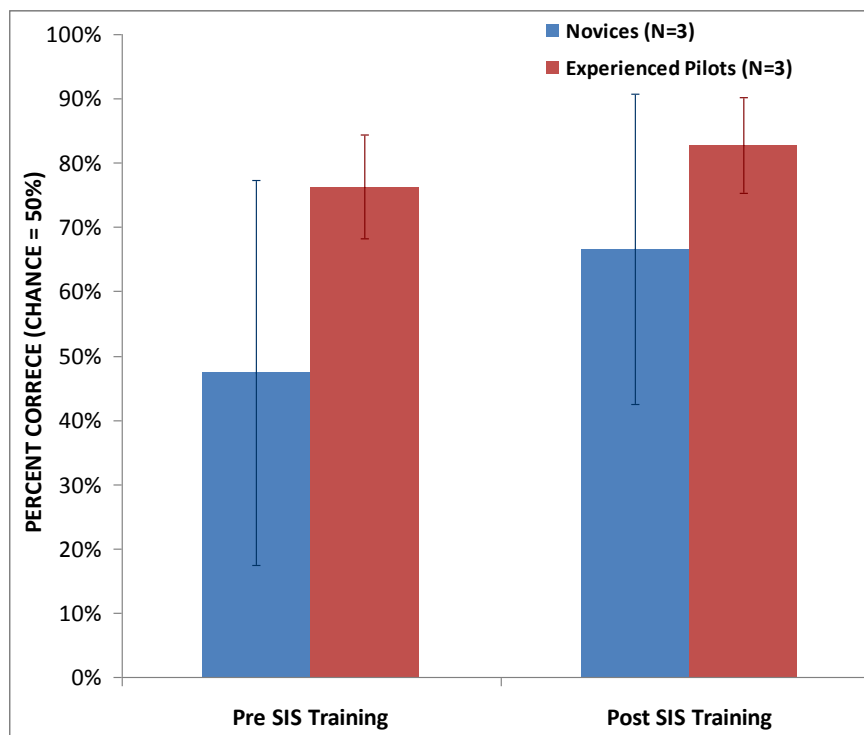


Figure 4. Instrument Failure Video (IFV) Task Accuracy as a function of Novice and Experienced Pilot Participants (Error bars represent Standard Deviation).

These data are only preliminary and further analyses of what is driving this result in terms of cognitive versus perceptual processing is beyond the scope of this paper, yet what is evident from these findings is that despite the level of transfer evident, there remains a disconnect between the cognitive skills and the perceptual skills developed within the stylized SIS training task and how these skills transfer firstly to a realistic SIS task, and then to a more dynamic environment (IFV task). There appears to be an unbridged gap between the skills developed on the stylized and realistic SIS tasks. Considering the similarities in the cognitive demands of these two tasks, this gap is likely to be largely perceptual and hence does not translate perfectly across even superficial changes in task appearance. There seems to be an even greater gap between these static skills and the

dynamic skills required to complete the IFV task. As task complexity increases, there is also an increase in the complexity of interactions between the necessary cognitive and perceptual skills, potentially leading to significant issues for performance if these skills are not developed in harmony.

While this study has only provided data from a small number of participants, the development of cognitive and perceptual skills within this type of game-like training tool highlight significant concerns for the potential for such skills to transfer effectively to any real world environment. That is, the gap between the game-like training environment and that of the real world is substantially greater than the gap constructed between static and dynamic training tasks, and as such any potential training transfer is likely to be reduced even further. It is an open question as to how big a role each factor contributing to this gap plays. The verisimilitude of the simulated environment is likely to be only one contributor, the nature of the task being performed and its immediate consequences (i.e., the trainees are not in control of the virtual aircraft nor is there any risk of bodily harm in either of these tasks) are also more than likely to play significant roles.

As highlighted by the current findings, when attempting to develop perceptual or cognitive skills it is not sufficient to train either of these skills in isolation (not to mention training them in isolation from the relevant motor skills). While training components skills has clear benefits, they must be targeted within a meaningful environment that acknowledges the interaction between them. This is a particularly important lesson within serious games and game-like training tools where it is often (albeit not always) acknowledged that psychomotor and perceptual skills are not necessarily well-understood or fully represented, but the importance of developing cognitive and decision-making skills is promoted (Roman & Brown, 2008). In many game-like training tools this may indeed prove to be problematic; and it remains important to demonstrate that the interaction between these skills is correctly developed and is plastic enough to effectively transfer to the practical real world environment. Moreover, the findings from this paper highlight that training transfer can be effectively evaluated within the laboratory environment without the need for expensive real world exercises.

References

- Gee, J.P. (2007). *What video games have to teach us about learning and literacy*. Palgrave Macmillan, New York, NY.
- Kellman, P.J., & Kaiser, M.K. (1994). Perceptual learning modules in flight training. *Human Factors and Ergonomics Society Annual Meeting Proceedings, Training, 5*, 1183-1187.
- McLean, G. M. T., Wise, L. Z. & Williams, B. (2011). A perceptual training module for pilot instrument scans. In G. Williams, P. Statham, N. Brown & B. Cleland (Eds.), *Changing Demands, Changing Directions. Proceedings ascilite Hobart 2011* (pp.842-846).
- Peck, M. (2012). Tools or toys: Training games are popular, but no one know how well they work. *Defense News*. <http://www.defensenews.com/article/20120115/DEFFEAT01/301150002/Tools-Toys>
- Roman, P. A., & Brown, D. (2008). Games—Just how serious are they? *The Interservice/Industry Training, Simulation & Education Conference (IITSEC)* (Vol. 2008).

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