The relationship between videogame use and learning to operate an Unmanned Aerial Vehicle

Kyle Fitzgerald

Department of Psychology

Macquarie University

10th June 2016

Authors Statement and Note on the Presented Thesis

I, Kyle Fitzgerald certify that the research presented in this thesis entitled “The relationship between videogame use and learning to operate an Unmanned Aerial Vehicle” is an original piece of research and has been written by me. I also certify that this thesis has not been previously submitted for a degree, nor has it been submitted to any institution other than Macquarie University. Sources of information are cited appropriately and acknowledged.

The thesis has been prepared in the form of a thesis by publication. As such there is a degree of repetition. References for all sections at the end of the paper.

Formatting and referencing style reflects the requirements of the APA Publication Manual (6th edition). The language reflects English (UK) spelling throughout.

The research presented in this thesis was approved by the Macquarie University Human Research Ethics Committee (reference

Signed

Kyle Fitzgerald

Contents

Synopsis

This thesis examines the relationship between videogame use and performance during the initial stages of learning to operate a line-of-sight Unmanned Aerial Vehicle (UAV). Study 1 demonstrated accumulated subjective estimates of action videogame experience explains the greatest proportion of variance in performance during a series of simulated UAV flight tasks. Study 2 indicates that videogame performance is also predictive of UAV flight performance, with a model containing both experience and in-game performance explaining the greatest proportion of variance in performance. Neither cognitive ability nor processing speed influenced this relationship, with inconsistent relationships observed between eye-movements in the two contexts.

Abstract

Videogame players have been proposed as a potential recruitment population to meet the growing demand for skilled Unmanned Aerial Vehicle (UAV) operators. This thesis examines the relationship between videogame use, both subjective estimates of experience and in-game performance, and performance during the initial stages of learning to operate a line-of-sight UAV. The research also explores the contributions of cognitive ability, information processing speed, similarity in task demands, and similarity in patterns of information acquisition as explanations of this relationship. Two studies were conducted. In Study 1, 41 participants completed a survey of subjective estimates of experience playing videogames, before completing assessments of cognitive ability and processing speed. Thereafter, they practiced take-offs, landings, and circuits using a simulated UAV. Accumulated, subjective estimates of lifetime experience playing action videogames explained the greatest proportion of variance in performance during the UAV flight tasks. Neither cognitive ability nor processing speed influenced this relationship. In a second study, 53 participants completed a survey of videogame experience, before playing three action videogames, during which their in-game performance was recorded. UAV performance was assessed during a UAV Test Task that followed exposure to periods of training involving take-offs and landings. Eye-movements were recorded throughout the videogame and UAV fight tasks, with subjective estimates of task demands measured following each task. In-game performance was positively associated with performance on the UAV Test Task, although a model containing both subjective estimates of action videogame experience and in-game performance explained the greatest proportion of variance in performance on the UAV Test Task. There was no evidence to suggest that this relationship was dependent upon similarities in task demands, and the results pertaining to information acquisition were inconsistent. The implications are discussed for recruitment and selection of UAV operators in the future.

General Introduction

The growing use of Unmanned Aerial Vehicles

Since their early use by the Israeli military for reconnaissance purposes, UAVs have been used increasingly across the armed forces, with a rapid acceleration in their use throughout the conflicts in Iraq and Afghanistan (United States Air Force, 2005; Singer, 2009). The expanded use of UAVs for military purposes is set to increase with heavy investment in UAV systems (Gertler, 2012) and the United States Air Force intending to increase the numbers, scope and integration of UAVs within both combat and peacetime forces (United States Air Force, 2005). The growing role of UAVs in the US military is being rapidly followed globally, with most major military organisations now operating or developing UAV capabilities (Wilson, 2013). While the primary role of UAVs within the military continues to be reconnaissance, they are being employed increasingly in combat operations (Singer, 2009).

UAVs have some significant advantages over manned aircraft for the military. A primary benefit of UAVs, as with all unmanned systems, is that they greatly reduce the risk and consequences of losses, enabling their use in missions that are too dangerous for manned aircraft (Singer, 2009; Nutwell, 2000; United States Air Force, 2005). UAVs can also remain airborne for longer periods than manned aircraft and, when combined with their ability to transmit high-quality real-time video-feeds, enables decision makers to have access to critical information to maintain their understanding of operations (Nutwell, 2000; United States Air Force, 2005). This ability to safely and cost-effectively maintain high levels of awareness, is a key reason for the growing utilisation of UAVs within militaries around the world (Singer, 2009). The lack of pilot and the associated life-support mechanisms allows UAVs to be built smaller and lighter, enabling them to fly at higher and at lower altitudes than is possible for a manned aircraft (United States Air Force, 2005). Finally, UAVs are less expensive than conventional aircraft to operate in comparison to manned aircraft, with lower costs for pilots

and maintenance (United States Air Force, 2005). These benefits are not restricted to the military context, and have resulted in an increase in the use of UAVs for civilian purposes (Air & Space Europe, 1999).

Over the past decade, UAVs have been utilised increasingly across a range of industries, primarily for their ability to enable information gathering and other activities cost-effectively and safely. In agriculture, they are being used for crop spraying and monitoring, weed control and assessing soil conditions (Urbahs & Jonaite, 2013; Herwitz et al., 2004). They are also being employed for weather and environmental monitoring, both for research and commercial purposes (Darack, 2012). In conservation, UAVs are being used to monitor wildlife (Watts et al., 2010) and to produce imagery for archaeological purposes (Chiabrando, Marenchino, Nex, Piatti & Rinaudo, 2009). UAVs are also being used to enhance maritime safety, observing and tracking icebergs (McGill, Reisenbichler, Etchemendy, Dawe & Hobson, 2011). Finally, UAVs are being used throughout the media industry including journalism, television, cinema, and sports broadcasting (Culver, 2014; Air & Space Europe, 1999).

Like the military use of UAVs, their use in civilian operations can give a greater level of awareness to decision makers, delivering real-time information with high-resolution imaging and sensors which can be interpreted concurrently (Urbahs & Jonaite, 2013; Chiabrando et al., 2009). They are able to fulfil the dirty, dangerous and monotonous work that would not be safe nor desirable for a human or a manned vehicle (Urbahs & Jonaite, 2013; Darack, 2012) and they are comparatively cheap to operate, with a single UAV capable of fulfilling a variety of applications (Urbahs & Jonaite, 2013).

Despite their advantages, the use of UAVs remains subject to a number of serious limitations. They require a continuous remote connection to the operators and, as they become increasingly sophisticated with a greater reliance on sensors, they require a higher

communication bandwidth to operate effectively (United States Air Force, 2005). In situations where a connection to the UAV is severed, the vehicle can lose control and crash, presenting a serious problem for both combat (United States Air Force, 2005) and civilian operations (Clothier, Palmer, Walker & Fulton, 2011). Human error presents a further challenge, as the operators must work in a remote setting, with degraded information, and are deprived of many of the additional sensory cues to which pilots of manned aircraft may have access, including the 'feel' of the aircraft (Triplett, 2008). The risk of disconnection, alongside a high risk of human error, means that UAVs have a lower reliability and a much higher accident rate compared to manned aircraft (Williams, 2004; Waraich, Mazzuchi, Sarkani & Rico, 2013). This heightened accident risk presents a serious problem when used in civilian airspace and draws attention to the need for highly skilled operators.

The increasing use of UAVs in civil airspace has led governments to impose a wider range of regulations for their use, particularly for operations in and around populated areas (Clothier et al., 2011). For example, the Australian Civil Aviation Safety Authority requires UAV pilots to have a UAV Operator's Certificate to operate in Australia (Civil Aviation Safety Authority, 2002). As UAVs become a more common tool, there is likely to be an increasing focus on selection and training to ensure the competency of operators, and particularly those operating within civil airspace.

What skills/abilities do UAV pilots need?

To guide recruitment and selection strategies of UAV operators, Barnes, Knapp, Tillman, Walters and Velicki (2000) conducted an assessment of 30 UAV pilots, who were trained to operate the Hunter, a military grade 'over-the-horizon' UAV. The aim of the assessment was to determine the skills required to operate a UAV using the Air Vehicle Operator Job Assessment Software System, which purports to measure individual skills and abilities needed for a task. The analysis revealed that the most critical competency for a UAV

pilot in this context is communication. Additional skills of import included perception and problem solving, followed by fine motor ability. Similarly, Kay, Dolgin, Wasel, Langelier and Hoffman (1999) identified cognitive ability, hand-eye coordination and psychomotor ability, motivation, the ability to deal with stress, and knowledge of the vehicle as skills necessary for skilled UAV pilots.

The population originally targeted for selection into the United States Air Force UAV programs comprised experienced pilots from manned combat aircraft (Triplett, 2008; United States Air Force, 2005). It was reasoned that experienced pilots of manned aircraft would learn to fly UAVs at a faster rate than non-pilots (Schreiber, Lyon, Martin & Confer, 2002). However, in assessing the need to use experienced pilots as operators of UAVs, Barnes et al. (2000) concluded that, while there were many skills that were used in both tasks, previous flight skill was not a necessary prerequisite in learning to operate a UAV. Further, as the use of UAVs has expanded, greater demand has been placed on the limited supply of experienced pilots, making it no longer feasible to continue recruiting UAV pilots from this pool in isolation (Barnes et al, 2000; Triplett, 2008; United States Air Force, 2005).

There are, in fact, a number of differences between operating a UAV and a manned aircraft, which may limit the transfer of experience. Following interviews with experienced manned aircraft pilots about the features of flying a UAV, Triplett (2008) identified a number of differences in the task demands and skills employed between UAV operations and manned aircraft. One difference is the slower pace of UAV operations compared to most manned aircraft in both flight speed and the pace of operations, together with the extended length of time of UAV missions (Triplett, 2008). There is also a perception amongst the pilots that flying the UAV is not as interesting as manned flight, which has been a source of demotivation for experienced pilots (Triplett, 2008).

UAV operations can be markedly dissimilar to manned aircraft in the visual information available to the pilots (Triplett, 2008). As the pilot of a UAV operates the vehicle remotely, there is no access to many of the critical cues that are used for manned flight (such as the feel of the plane). Further, the cues present are often degraded in comparison to manned flight (with the visual information being likened to a flight simulator). Therefore, UAV pilots must operate the UAV with restricted information, which is bound by what can be observed through video monitors. Finally, the operation of an over-horizon UAV is characterised more by monitoring and communicating information, rather than by exercising the flight skills that are necessary for manned flight (Triplett, 2008).

After examining the capabilities needed for UAV operations, Barnes et al. (2000) concluded that it was not cost effective to continue to rely on experienced pilots and that, with training and experience, non-pilots could become as effective as experienced pilots in operating a UAV. With the demand for UAV pilots having increased beyond the supply of experienced pilots, the requirement for previous flight experience is considered no longer viable, nor cost effective (U.S. Government Accountability Office, 2014). As a result, organisations, such as the United States Air Force have created a dedicated career path for UAV operations, using candidates without previous flight experience (United States Air Force, 2005; U.S. Government Accountability Office, 2014). However, the supply of UAV pilots has failed to meet the demand for operators (U.S. Government Accountability Office, 2014). As a result, there is an urgent need to develop innovative training programs and/or alternative selection methods to identify candidates for UAV operations (United States Air Force, 2005). One population that might fulfil the growing demand for UAV pilots is video game players (Triplett, 2008).

Videogames and UAVs

Triplett (2008) identified parallels in a number of skillsets required for successful videogame play and UAV operations. These similar skillsets include: a high need for focus and concentration, communication and teamwork, hand-eye coordination and precision, the ability to continuously monitor large amounts of information from multiple sources and modalities, the ability to multi-task, rapid decision making, maintaining situation awareness, and a high capacity for procedural memory. These similarities led Triplett (2008) to conclude that videogame experience may provide a skills advantage which may lead to superior aptitude in learning to operate a UAV.

The utility of videogame players as a source of UAV operator recruits has been highlighted by McKinley, McIntire and Funke (2011) who compared pilots, experienced videogame players, and non-gamer/non-pilots in landing a Predator UAV, a military grade 'over-the-horizon' UAV, in a simulation task. The participants also completed a battery of ability measures associated with UAV flight performance, namely cognitive ability, information monitoring, motion monitoring and target identification. Performance on the UAV landing task was measured using three critical indicators of landing the vehicle safely, including the slope of the landing glide, the vertical decent speed, and the speed at landing. While pilots performed significantly better than videogame players in one aspect of the landing task, namely landing speed, videogame players performed significantly better than non-gamers in learning to successfully land the UAV in all three performance measures. Further, videogame players performed as well or better than pilots in the ability tasks, with both groups tending to outperform non-gamer/non-pilots. These results suggest that, while pilots' flight experience yields a slight advantage in in the initial stages of learning to fly a UAV, this difference is minimal over videogame players with minimal or no flight experience. Further, the results indicate that experienced videogame players may learn to

operate a UAV more quickly than non-videogame players over an extended period. The relationship between videogame experience and UAV flight performance also suggests that videogame technology could be used as a potential training tool.

Transfer of videogame experience to other real-world tasks

Videogame technology has been used previously as a means of enhancing piloting capabilities, most notably within the Israeli Air Force where it been used as a supplement to flight training programs. Custom-designed videogames have been used to teach cognitive skills such as anticipation and planning in aerial combat (Barnes et al., 2000). The use of videogames as a training tool is based on evidence that demonstrates an association between playing a video-game designed to train cognitive skills and subsequent flight performance.

Gopher, Weil and Bareket (1994) found that cadet pilots who played a custom-designed computer game demonstrated superior skills during a flight task in comparison to a control group. During their initial training, cadets spent 10 hours playing ‘Space Fortress’, a videogame that was custom-designed to utilise cognitive abilities associated with flight performance. Importantly, Space Fortress did not directly teach flight skills nor the use of equipment. Following standard flight training, the pilots were tested on their flight performance and they outperformed pilots who had not played Space Fortress. This led Gopher et al. (1994) to conclude that the experience playing Space Fortress developed the capabilities which underlay flight performance in the cadets, capabilities which enhanced their later flight performance.

The relationship between videogame experience and performance in professional tasks has been observed beyond UAV operations, in particular amongst laparoscopic surgeons. Rosser et al. (2007) assessed the frequency of videogame use amongst thirty-three surgeons prior to completing a laparoscopic surgery procedure. Surgeons who regularly played videogames tended to perform the laparoscopic surgical procedures significantly

faster and with fewer errors compared to surgeons with limited or no videogame experience (Rosser et al., 2007). Moreover, those surgeons also completed a videogame task, with surgeons who scored in the top quartile of in-game performance tending to make significantly fewer errors and complete the surgery tasks in significantly less time than surgeons who performed relatively poorly on the videogame task. Rosser et al. (2007) concluded that the positive relationship between videogame experience/performance and surgical performance was most likely due to the transfer of skills from one domain to the other.

Consistent with Rosser et al. (2007), Rosenberg, Landsittel and Averch (2005) compared the laparoscopic surgical performance of 11 students with no surgical experience with their performance on three commercially available videogames. Higher videogame performance was associated with faster completion of the surgical procedure while sustaining a corresponding level of accuracy in the task (Rosenberg et al., 2005). Similarly, Badurdeen et al. (2010) observed a strong association between performance on three videogames and performance during a simulated laparoscopic surgical task, together with a laparoscope skills test. These observations led both Rosenberg et al. (2005) and Badurdeen et al. (2010) to conclude that videogame technology could be used as a training tool for surgical students. Further, the relationship observed between videogame performance and performance in the surgery task led them to suggest the possibility of using this technology as a capability assessment tool for the selection of future surgeons (Rosenberg et al., 2005; Badurdeen et al., 2010).

In combination, the evidence from these piloting (Gopher et al., 1994) and surgery studies (Rosser et al. 2007; Rosenberg et al., 2005; Badurdeen et al., 2010) provide empirical support for Triplett (2008) and McKinley et al.’s (2011) assertion that videogame experience is associated with skills or abilities that can then be applied in other tasks, including operating a UAV, piloting manned aircraft, and surgery. This relationship suggests that experience in

the use of videogames may provide a beneficial training and assessment tool across a variety of related fields.

Transfer of training

Training is defined by Grossman and Salas (2006) as the "systematic acquisition of knowledge, skills and attitudes that improve performance in a specific environment" (p. 104). As a result, the effectiveness of training interventions is typically measured by the positive transfer of training. Transfer of training is the extent to which a training intervention produces a meaningful alteration (generally improvement) in behaviours or attitudes, leading to improved workplace performance (Grossman & Salas, 2006). A critical aspect of the effectiveness of training is the generalisation of the learning outcomes.

Generalisation refers to the degree to which a learned skill is able to be successfully applied across different problems and contexts (Blume, Ford, Baldwin & Huang, 2010). Yellon and Ford (1999) suggest that the generalisation of training can be placed on a continuum of the adaptability of the training task to different applications. This continuum is bounded by 'closed' tasks at one end, in which the training task is highly prescriptive, with a 'correct' way of performing the task in a specific context (for example installing a child-seat in a car). At the other end of the spectrum are open skills, where the training task is designed to be generalised to different problems and can be employed across different contexts (e.g. motivating employees). The transfer of training literature suggests that the degree of adaptability of the training task interacts with individual differences amongst players (Grossman & Salas, 2006).

In a review of the transfer of training literature, Grossman and Salas (2006) highlighted individual differences amongst the learners, such as cognitive ability and personality, as having a substantial impact on the ability of learners to enact learned behaviours in their work. In a meta-analysis of factors influencing transfer of training, Blume

et al. (2010) noted that cognitive ability was a positive predictor of the transfer of training with a moderate effect size. This relationship between cognitive ability and the transfer of training was stronger in open tasks than in closed tasks suggesting that cognitive ability is more predictive of the transfer of training for skills that can be employed across a range of different tasks and contexts. As a result, the transfer relationship between videogame experience and performance in other tasks may not be as simple as to whether it is a product of innate ability or learning, and instead, may be the result of a more complex interchange between individuals' ability and their videogame experience. For example, if an individual has a high degree of videogame experience but has a low level of cognitive ability then his/her performance in a novel yet related task, such as flying a UAV, may not result in a demonstrable transfer of training.

Skills and abilities associated with playing videogames

There is a growing body of evidence to suggest that exposure to videogames is associated with superior cognitive and perceptual abilities (Connolly, Boyle, MacArthur, Hainey & Boyle, 2012; Ferguson, 2007). Following a meta-analysis of seven studies relating to videogames and visuospatial cognition, Ferguson (2007) concluded that exposure to videogames was associated with positive outcomes for the player, in the form of heightened visuospatial cognition. Similarly, reviews of the literature by Connolly et al. (2012) and Green and Bavelier (2015) also note positive relationships between videogame use and a range of cognitive and visual perception skills.

In examining the association between videogame use and cognitive and perceptual capabilities, a distinction needs to be drawn between action and non-action videogames. Action videogames are games that are fast-paced, involve multiple, fast moving objects, are unpredictable, and require the player to constantly scan the environment to detect and quickly respond to targets (Green, Li & Bavelier, 2010). Popular examples of action videogames

include the ‘Call of Duty’ and ‘Grand Theft Auto’ series. In contrast, non-action videogames, such as ‘The Sims’ or ‘Civilisation’, tend to place fewer demands on the players in terms of temporal and attentional demands (Achtman, Green & Bavelier, 2008). The evidence base for the association between videogame use and heightened cognitive and perceptual capabilities is drawn primarily from two sources, cross-sectional studies comparing action videogame players with non-videogame players, and training studies where non-videogame players are exposed to a specified action videogame for between 10-50 hours.

A number of cross-sectional studies have demonstrated that experienced, action videogame players outperform non-videogame players across a range of cognitive and perceptual capabilities (Connolly et al., 2012; Bavelier, Green, Pouget & Schrater, 2012). Some of these areas include: faster visual search, with an increased span of visual attention per unit of time (Green & Bavelier, 2003; Green & Bavelier, 2006; Clarke, Fleck & Mitroff, 2011); a better ability to track multiple objects within the visual space under time pressure (Green & Bavelier, 2003; Green & Bavelier, 2006; Sungar & Boduroglu, 2012); a greater capacity to distribute attention and coordinate two concurrent tasks (Strobach, Frensch & Schubert, 2012); a reduced cost of switching attention within the visual environment (Strobach et al., 2012; Green & Bavelier, 2003); faster reaction speeds while maintaining accuracy (Castel, Pratt & Drummond, 2005; Dye, Green & Bavelier, 2009; Chisholm, Hickey, Theeuwes & Kingstone, 2010; McDermott, Bavelier & Green, 2014); greater change detection (Clarke et al., 2011); a reduced susceptibility to innattentional blindness (Vallet, Lamb & Annetta, 2013); and heightened visual short-term memory with more accurate recall of shapes and colours (Wilms, Petersen & Vangkilde, 2013; Blacker & Curby, 2013; McDermott et al., 2014; Sungar & Boduroglu, 2012).

Comparisons between experienced videogame players and non-videogame players highlight capabilities where action videogame players demonstrate superiority. These

associations indicate that the use of action videogames may develop and enhance these capabilities more generally. However, while there is evidence to suggest that there is a relationship between videogame experience and cognitive capability, this association could also be explained by natural ability that is then evident in both tasks (Connolly et al., 2012). As a result, while being able to highlight many areas of difference, these cross-sectional studies are unable to provide a conclusive judgement as to the causal links of the relationship. Consequently, the assertion that the use of action videogame improves cognitive and perceptual capability tends to rest upon the outcomes of 'training' studies.

The training study design utilises a random-controlled trial methodology, involving non-videogame players receiving a pre-measure of the targeted capability before being exposed to a specified action videogame for 10-50 hours, and then a post-exposure measure of the targeted capability (Green & Bavelier, 2003; Green & Bavelier, 2015). These pre and post measures are then compared against controls who did not play the specified videogame. These training studies have been used to provide empirical support for many of the observations from cross-sectional studies, including; faster visual search speed (Green & Bavelier, 2003), faster reaction speeds (Green & Bavelier, 2003; Strobach et al., 2012), enhanced switching of attentional resources (Green & Bavelier, 2003; Strobach et al., 2012), increased capacity to track multiple objects (Green & Bavelier, 2006), wider span of visual attention (Feng, Spence & Pratt, 2007; Franceschini et al., 2013), and increased mental rotation ability (Feng et al., 2007; Boot, Kramer, Simons, Fabiani & Gratton, 2008; Sims & Mayer; 2002). Overall, these training studies present compelling evidence that action videogame experience results in improvements to players' acquisition and processing of information.

Amount of training and the role of deliberate practice

A meta-analysis of cross-sectional and training studies undertaken by Powers, Brooks, Aldrich, Palladina and Alfieri (2013) noted that effect sizes from training studies tended to be substantially lower than those evident in cross-sectional studies. For example, following 21.5 hours of exposure to action videogames, Boot et al. (2008) failed to observe any improvement across a range of cognitive or perceptual capabilities, including visual attention, visual short-term memory and spatial processing. However, comparisons of experienced videogame players with non-videogame players did demonstrate the expected heightened performance amongst the experienced videogame players (Boot et al., 2008).

An explanation for the inconsistency noted by Powers et al. (2013) and Boot et al. (2008) in the relationship between videogame use and cognitive and perceptual abilities is perhaps related to the amount of exposure delivered in training studies, and whether this is sufficient to facilitate meaningful improvements in performance. Typical training studies expose non-videogame players to between 20 and 50 hours of videogame activity over a two to five week period (Green & Bavelier, 2003; Green & Bavelier, 2006; Strobach et al., 2012; Boot et al., 2008). This contrasts with the 13 years of experience that is typical of videogame players (ENTERTAINMENT SOFTWARE ASSOCIATION, 2015) with an average of 6.5 hours of gameplay per week (Flamberg, Pike & Woodrick, 2014). As a result, heightened performance may only be evident following regular action videogame activity, accumulated over a lengthy period.

The need for lengthy and consistent experience is echoed by Ericsson and Charness (1994) who, following a review of the expertise literature, concluded that, in addition to ability, lengthy and sustained practice was required to develop and sustain the cognitive capabilities that underpin heightened performance. They note that high performers tend to begin their intensive training at an early age, which must be maintained to sustain improved

performance. By engaging in this intensive training regimen from an early age, learners develop their skills and knowledge beyond what is typical of individuals who did not begin training during their youth, including their ability to perceive and process information and rapidly engage an optimal response (Ericsson & Charness, 1994).

The fact that extensive experience is usually required to produce heightened performance is typically not reflected in studies involving the generalisation of videogame skills. The vast majority of the research tends to focus on the recent experience of the player, with most cross-sectional studies examining experience within the six-month period preceding the study (Castel et al., 2005; Green & Bavelier, 2003; Green, Sugarman, Medford, Klobusicky & Bavelier, 2012; Strobach et al., 2012; West, Al-Aidroos & Pratt, 2008). While the object of these studies is to compare videogame players against non-gamers, there is a risk that this focus on recent use fails to capture the longer term impact of videogame use. In particular, the short timeframe in these studies may not capture the accumulated effects of regular, intense practice from childhood that Ericsson and Charness (1994) highlight as having a substantial impact on the development of heightened information acquisition that is typical of experts.

Information acquisition

In addition to associations with heightened performance in singular cognitive or perceptual capabilities, Green et al. (2010b) and Bavelier et al. (2012) argue that action videogame experience enhances players' ability to acquire and integrate sensory information, resulting in a superior capability for cognitive tasks like decision making. Using the previously described training study protocol, Green et al. (2010a) demonstrated that exposure to action videogames improves the accuracy of the player's probabilistic inferences in visual and auditory tasks. Participants who played an action videogame for 50 hours were more accurate than controls in determining the net direction of a dynamic dot display which had

various levels of coherence with the direction of the dots. Similarly, following 50 hours of action video game experience, participants were more accurate in detecting a pure auditory tone of varying amplitude hidden within a mask of white noise. These observations led Green et al. (2010a) to conclude that playing action videogames improves the efficiency of information capture and integration alongside a greater ability to identify patterns in sensory information. Bavelier et al. (2012) argue that it is this enhanced ability to perceive and understand their environment which underpins the exceptional performance of action videogame players, compared to non-gamer peers. Moreover, this enhanced capacity to identify and integrate information as a result of extensive experience is echoed by studies of expertise in other domains (Klein, 1998; Farrington-Darby & Wilson, 2006).

Klein (1998) argues that a defining feature of experts is their exceptional performance, knowledge, and judgement compared to less experienced individuals. A critical component of this heightened performance is a greater ability, compared to less experienced individuals, to identify and focus on the critical information within a task, drawing this information together to develop a meaningful understanding of the situation (Klein, 1998). When perceiving a relevant visual scene, experts are more accurate in their understanding of the scene and in their predictions of future events, as well as making more accurate decisions in a shorter timeframe (Mann, Williams, Ward & Janelle, 2007; North, Williams, Hodges, Ward & Ericsson, 2009). This enhanced ability to understand and respond to stimuli may reflect a difference in the manner in which experts acquire and utilise information in their domain of expertise; a difference which can be observed by comparing eye-movements between experts and less experienced individuals.

Two meta-analyses comparing the eye-movements of experts with less experienced individuals (Mann et al., 2007; Gegenfurtner, Lehtinen & Saljo, 2011) demonstrate that, when viewing visual information within their area of expertise, experts display different

patterns of eye-movements in comparison to less experienced individuals. Similarly, a meta-analysis of 42 studies of expert sportspeople revealed that experts made fewer fixations and fixated for longer durations compared to novices (Mann et al., 2007). Finally, a meta-analysis of 65 studies of eye-movements amongst experts across a diversity of domains, including sports, medicine and transportation, revealed that experts had lengthier saccades, fixated for shorter lengths of time on irrelevant information, and fixated for longer on task relevant information (Gegenfurtner et al., 2011). These results suggest that experts are more efficient in their visual search and are better able to direct their attention towards task-relevant information. Therefore, they require less time to identify and discriminate task-relevant features from task-irrelevant features, together with a capability to attend to a wider range of the visual space (Mann et al., 2007; Gegenfurtner et al., 2011).

The expertise literature also suggests that these differences between the eye-movements of experts and non-experts are the product of experience (Gegenfurtner et al., 2011; McCarley, Kramer, Wickens, Vidoni & Boot, 2004). McCarley et al. (2004) examined the eye-movements of sixteen novices as they observed x-rays of baggage across five sessions, and noted that, as they became more experienced with the task, they required fewer saccades to correctly identify whether a target item was present. Further, when comparing studies of eye-movement amongst various levels of expertise across a range of professions, Gegenfurtner et al. (2011) noted that the eye-movements of intermediate practitioners reflected a mid-point between novices and experts. As a consequence, it appears that, as individuals become more experienced with a task, their acquisition and processing of visual information changes towards patterns that tend to be typical of experts.

Studies of eye-movement behaviour amongst experts hold a number of considerations for Green et al.'s (2010a) and Bavelier et al.'s (2012) assertion that videogame experience alters the information processing capabilities of the player. The expertise literature

(Gegenfurtner et al., 2011; Mann et al., 2007; North et al., 2009; Charness, Reingold, Pomplun & Stampe, 2001) suggest that individuals with higher levels of experience demonstrate a greater capacity to scan the visual space and locate and focus on the relevant pieces of information. This is consistent with the outcomes of many of the studies concerning the impact of action videogame exposure, which suggest that action videogame experience is associated with enhance perceptual and attentional capabilities that allow the player to more effectively scan and attend to relevant information in the task environment (Green & Bavelier, 2003; Strobach et al, 2012; Feng et al., 2007; Green et al., 2010a). Further, Mann et al. (2007) and Gegenfurtner et al. (2011) suggest that this faster and more targeted information acquisition ability is reflected in eye-movement behaviour, with greater levels of experience tending to coincide with a more efficient pattern of information acquisition. Typically, this involves short fixations on task irrelevant information, lengthy fixations on task relevant information, and lengthier saccades reflecting a wider dispersion of fixations (Gegenfurtner et al., 2011). However, to date, no published study has examined the association between experience and eye-movements within the videogame context, nor is there any published research which explores the relationship between eye-movement behaviours in videogames and UAV-related tasks.

The expertise literature presents a further consideration for the potential role of information acquisition in the transfer of learning between videogames and UAV operations, in that expertise tends to be closely linked to a particular domain or context (Charness & Tuffiash, 2008; Farrington-Darby & Wilson, 2006; Kirkman, 2013). However, evidence from the sports domain suggests that the transfer of expertise is possible when the two tasks are sufficiently similar in terms of the underlying constructs (Smeeton, Ward & Williams, 2004). For example, Smeeton et al. (2004) demonstrated that, following the presentation of sports footage, experienced sportspeople recorded higher rates of recall, compared to inexperienced

players, in their own sport and in similar sports, while demonstrating lower levels of recall when presented with footage from a dissimilar sport. This propensity towards similarity has also been suggested within the videogame domain by Green et al. (2012) who hypothesised that, for transfer to occur from videogames to other tasks, there needed to be some similarity between the game task and the transfer task.

Similarity in demands

Oei and Patterson (2014) suggest that the apparent relationship between action videogame experience and performance in other tasks is dependent upon the similarity in the demands in the videogame and transfer tasks. If both the videogame and the transfer task contain a similar set of underlying cognitive and perceptual demands, then they will draw on corresponding capabilities which are required to overcome these demands. These are capabilities that are common to both tasks. Theoretically, when players engage in a videogame task, they strengthen these common capabilities, which in-turn produces heightened performance in other tasks that draw upon the same capabilities (Oei & Patterson, 2014).

Support for Oei and Patterson's (2014) claim that transfer requires some similarity in task demands can be drawn from studies that associate experience with particular types of videogames. For example, 14 hours of exposure to Tetris, a puzzle game where the player rotates shapes to fill in gaps, is associated with improvements in mental rotation ability, but only for shapes that are similar to those used in Tetris (Sims & Mayer, 2002). Boot et al. (2008) also noted a degree of similarity between the type of game and the associated improvement in skills, with exposure to Tetris only relating to increases in mental rotation ability and not to any other capability, such as shifting attention. While these studies demonstrate an association between videogame task demands and improvements in

corresponding capabilities, neither systematically manipulated the types of demands to which the player was exposed (Oei & Patterson, 2014).

Oei and Patterson (2015) assigned non-video players to one of four game training groups, with each game containing different levels of five relevant task demands that related to action videogame experience; game speed, switching of attention, object tracking, attention, and visual searching. The measures of the corresponding capabilities for each of these demands revealed significant differences between the games in improvements in capability following 20 hours of gameplay. Specifically, the first-person shooter game, which contained higher levels of temporal, attentional, and object tracking demands than the other tasks, was associated with a significantly greater level of improvement in attentional and object tracking capabilities than were the other three game tasks. As a result, it appears that the transfer of training from videogame tasks to other tasks may require a level of consistency in the demands experienced between the two tasks (Oei & Patterson, 2015).

Baniqued et al. (2013) presented a similar argument stating that videogames are not ‘process pure’ experiences which uniformly draw on the same capabilities, but instead, that different games require different levels of capabilities for the player to succeed. As a result, while action videogames share many common features, such as temporal demands and a need for visual scanning, individual games present a unique combination of demands for the player to overcome which, in turn leads to the development of different capabilities. For example, the evidence from training studies indicates that first-person shooter games, which require the player to rapidly scan and respond to the presence of multiple fast-moving targets, are associated with improvements in attention switching, tracking of multiple objects, reaction speeds, and visual scanning (Green & Bavelier, 2006; Strobach et al., 2012; Oei & Patterson, 2015). However, first-person shooter games are not associated with improvements in mental rotation ability (Boot et al., 2008), a demand that does not feature in first-person shooter

games. Baniqued et al.'s (2013) assertion that the different action videogames have different developmental impacts on the player may have implications for the investigation of the relationship between videogame use and learning to operate a line-of-sight UAV.

Conclusions

The evidence available thus far offers potential support for the use of videogame players as a recruitment stream for UAV operations. In addition to the association between videogame experience and performance on a UAV landing task noted by McKinley et al. (2011), there is evidence from other domains, namely aviation (Gopher et al., 1994) and medicine (Rosser et al., 2007), to indicate that a relationship may exist between playing videogames and performance on other, related tasks. While the mechanisms leading to the transfer between tasks remain unclear, the results from various training and cross-sectional studies suggest that exposure to videogames is associated with heightened capabilities in information processing which, ultimately, may underpin heightened performance in UAV operations.

Over the last 25 years, videogames have become a mainstream entertainment medium (Connolly et al, 2012), with an estimated 58% of the United States population now playing videogames (Entertainment Software Association, 2013). The average videogame player in the United States is 35 years old and has been playing videogames consistently for 13 years (Entertainment Software Association, 2013). Further, the now widespread use of videogames begins at an early age with the average 10 year old playing for 12.7 hours per week (Greenberg, Sherry, Lachlan, Lucas and Amanda, 2010). This continues into adulthood with the average American college student playing for 12.1 hours per week (Greenberg et al., 2010). The end result is that, by the age of 21, the average person has spent thousands of hours in gameplay.

While the potential to utilise experienced videogame players as UAV pilots has empirical support in the literature, there remain a number of continuing questions. One of the most pressing questions concerns whether videogame tasks could play a role in operator selection by presenting a means of assessing the capability of prospective operators. Studies within the context of laparoscopic surgery have demonstrated a relationship between performance in action videogame tasks and subsequent surgical performance amongst both experienced surgeons (Rosser et al., 2007) and novices (Bardurdeen et al., 2010). In the case of both studies, performance in the three, commercially available videogames explained a greater proportion of variance in surgical performance than did self-reports of experience. As a result, there is the prospect that actual performance in videogame tasks may present a more accurate and comparable predictor than self-reports of prior experience.

In explaining the relationship between videogame experience and performance in other contexts, Green et al. (2010a) and Bavelier et al. (2012) argue that information processing is the mechanism responsible. Specifically, exposure to the perceptual and cognitive demands within the videogame task enhances the ability of the player to efficiently acquire, process, and respond to perceptual information. As a consequence, this enhanced information processing ability enables superior performance in tasks with equivalent temporal and attentional demands.

The expertise literature (Mann et al., 2007; Gegenfurtner et al., 2011) suggests that this heightened information acquisition capability is visible in the differences in eye-movement behaviours as a function of experience. Oei and Patterson (2014) suggest that a consistency in demands is required for there to be a transfer of this enhanced information acquisition capability. However, to date there have been no studies that examine the relationship between similarity demands and eye-movement behaviours in a videogame context. These issues were explored in the following studies to identify whether similarity in

information processing demands affect the relationship between videogame experience and UAV operations, and within this context, whether there is a relationship between information acquisition and the transfer of videogame experience to performance in operating a line-of-sight UAV.

The Present Studies

The rapid expansion in UAV operations has created a growing demand for UAV operators. The speed of adoption of UAV technologies means that there is a need for innovative means of recruiting, selecting, and training future operators. Videogame technology may offer a means of achieving these needs. However, if videogame technology is to be used for these purposes, a number of critical questions need to be answered, including whether there is a relationship between videogame experience and learning to operate a UAV, together with the nature of this relationship. The aim of the studies presented is to examine the relationship between videogame use and the initial stages of learning to operate a line-of-sight UAV, in addition to potential explanations for this relationship.

Study 1 was designed to examine whether there is a relationship between videogame experience and the initial stages of learning to operate a line-of-sight UAV. This study also examined the effect of accumulated videogame experience against recent videogame use alone on subsequent UAV performance. The type of videogame experience was also explored to identify whether the type of videogame experience is related to performance during the initial stages of operating a line-of-sight UAV. Finally, Study 1 explored the role of cognitive ability and processing speed in the relationship between videogame experience and learning to operate a UAV.

Study 2 was designed to replicate and extend the results of Study 1. The primary aim was to determine whether actual performance could offer a more reliable and accurate predictor of aptitude in learning to operate a line-of-sight UAV in comparison to self-reports

of experience. A secondary aim was to explore the impact of task demands, and specifically, whether a greater degree of similarity between the demands of the game and the initial stages of learning to operate a line-of-sight UAV would result in a stronger association between performance in the two tasks. Finally, Study 2 was designed to examine whether a relationship exists between experience playing action videogames and eye-movements as participants completed the videogame and UAV flight tasks, as well as whether a similarity exists in the patterns of eye-movements that participants adopt in the videogame tasks and the pattern that they adopt in learning to operate a line-of-sight UAV.

Study 1

In recent years, video games have gained increasing popularity and mainstream appeal, with an estimated 58% of the U.S. population now playing videogames (Entertainment Software Association, 2013). The widespread exposure to this immersive entertainment medium has led to a growing research focus on the impact of extended video game use on the player, with recent findings suggesting that extensive gameplay may improve performance in related cognitive and perceptual tasks (Connolly et al., 2012). As a result of these findings, organisations including the United States Airforce are seeking to establish how videogames can be used to improve selection and training outcomes, particularly for operators of Unmanned Aerial Vehicles (UAV) (Barnes et al., 2000; Triplett, 2008; McKinley et al., 2011). However, while there is evidence to demonstrate a transfer of learning between videogame experience and learning to operate a UAV (McKinley et al., 2011), the cognitive and perceptual basis for this relationship remains unclear. This study investigated the relationship between videogame experience and performance in learning to operate a line-of-sight UAV and the perceptual and cognitive factors that may assist in explaining the nature of this relationship.

UAV and videogame experience

The relationship between videogame play and learning to operate a UAV was initially demonstrated by McKinley et al. (2011), who established that regularly playing video games was positively associated with performance in learning to land a Predator drone. Videogame players, non-videogame players and experienced pilots were compared in their landing performance in a UAV simulator following six training sessions. Videogame players demonstrated superior performance in landing the simulated UAV, as measured by accuracy of glide slope, airspeed, and speed of descent, compared to non-videogame players. In turn, pilots demonstrated superiority to videogame players in the accuracy with which they

maintained the glide slope and airspeed. McKinley et al. (2011) suggests that, just as the pilots' experience transferred to improved performance on the UAV landing task, so does videogame experience. The basis of this relationship is likely to relate to the similarities in the cognitive and perceptual skills needed to cope with the demands associated with both tasks.

Following interviews with experienced gamers and pilots, Triplett (2008), concluded that there was substantial crossover in the skills required for both tasks. These included the monitoring of information for long periods of time, concentration, hand-eye coordination, precision in the use of controls, communication, and teamwork. These results led Triplett (2008) to conclude that videogame players may have advantages in learning to operate a UAV in comparison to the general population, as the cognitive and perceptual skills developed while playing videogames are similar to those encountered when operating a UAV. Consequently, the skills acquired in videogaming may be able to be deployed in response to similar demands associated with specific UAV operations.

The potential performance-enhancing qualities of videogames do not appear to be limited to UAV operations. For example, videogame experience has also been associated with improved performance in other tasks, including manned piloting and surgical skill. Gopher et al. (1994) observed that, at the conclusion of training, cadet pilots who played a videogame in addition to their flight training were rated with flight skills greater than pilots in a control group. Similarly, Rosser et al. (2007) noted that surgeons who had previous or current videogame experience performed a surgical procedure significantly faster and with fewer errors than surgeons without videogame experience. Further, when the surgeons completed a videogame task, those who were in the top quartile of in-game performance made significantly fewer errors and completed the surgery task faster than the bottom three quartiles. In combination, these results suggest that a relationship exists between videogame

experience and performance on other, related tasks. Grossman and Salas (2006) proscribe transfer of training as the degree to which the knowledge or skills developed in the learning environment produces a meaningful alteration in behaviours, typically resulting in improved performance, in other environments.

What learning occurs when playing videogames?

Perceptual learning is a hypothesised explanation for the potential transfer of learning between video game use and performance in other contexts (Green, et al., 2010a). Perceptual learning is the adaptive changes to an organism's perceptual system resulting from exposure to environmental demands (Goldstone, 1998). Following a review of the perceptual learning literature, Goldstone (1998) noted a number of mechanisms related to perceptual learning, including: weighing and directing attentional resources based on the salience of the information within the task; distinguishing and differentiating stimuli, and categorising this information based on the similarity or dissimilarity or features; the imprinting of stimuli which improves the speed and ability to accurately detect, process, and respond to regularly encountered stimuli; and joining associated features within a task to form patterns of features.

Videogame experience has been associated with superior performance in a number of perceptual tasks, including the ability to track multiple objects (Green & Bavelier, 2006); a lower susceptibility to innattentional blindness (Vallett et al., 2013); a capacity to differentiate visual and auditory stimuli (Donohue, Woldorff & Mitroff, 2010); and a lower performance cost when switching between attentional tasks (Green et al., 2012). Further, Green and Bavelier (2003) have suggested that videogame experience may increase the speed of processing of visual information.

Wilms et al. (2013) compared non-players, casual gamers and experienced players in visual attention and short-term memory and reported that regular gameplay is related to a greater encoding speed of visual information. Similar results were observed by Dye et al.

(2009) who examined the results of 89 reaction time experiments and concluded that videogame players have faster reaction times, while maintaining accuracy, compared to non-videogame players. Wilms et al. (2013) suggest that the basis for this improvement in the processing of visual information is due to the extensive experience acquired in coping with the information processing demands encountered during videogame play. Consistent with Goldstone's (1998) expectations concerning perceptual learning, it might be argued that players' perceptual systems adapt to the demands of the videogame to produce a lasting improvement in players' ability to respond to the features encountered in the videogame.

Action videogames produce perceptual improvements but not non-action games

Baniqued et al. (2013) suggest that not all videogames are associated with the same degree and form of cognitive and perceptual change. According to Cohen, Green and Bavelier (2007) and Green et al. (2010a), it is only experience playing action videogames that is associated with improvements in perceptual abilities. Green et al. (2010a) argues that this is due to the features that define an action videogame, including fast pace; the rapid identification of targets or important features; the rapid development and execution of plans by directing objects within the game space; the level of unpredictability; the requirement for attention to changes in the game space; and a need for visual scanning to perceive objects in peripheral vision. This led Achtman et al. (2008) to suggest that, for a videogame to result in substantive perceptual learning gains, it must be time-bounded with a fast pace of events; unpredictable, as this requires the player to engage in constant scanning of the visual field; require rapid responses to the presentation of stimuli; and provide rapid and consistent feedback on actions to reinforce behaviour, signal errors, and guide future responses. Further, games must be motivating, with an adaptable difficulty so that the task is challenging but still achievable.

Length of experience needed to improve perceptual performance

Despite the strong and consistent association between videogame use and performance in related tasks, there remains considerable debate as to the amount of videogame use necessary to effect improvements in perceptual abilities. Some research (Feng et al., 2007; Green & Bavelier, 2003; Green & Bavelier, 2006) suggests that short exposures of as little as 10 – 50 hours of playing action videogames results in significant improvements to perceptual performance. However, Boot et al. (2008) suggest that extensive experience, in both time and timespan, is necessary to produce improvements in perceptual performance.

Boot et al. (2008) observed that, while highly experienced videogame players (all of whom began playing videogames at an early age) outperformed non-videogame players in a number of cognitive and perceptual tasks, non-videogame players who completed a regimen of 21.5 hours of gameplay over a month did not demonstrate any significant improvements in a range of cognitive and perceptual tasks. They concluded that short exposure to videogames does not produce a substantial improvement to cognition or perception and that instead, the differences observed in performance between experienced videogame players and non-videogame players was the result of individual differences and/or the lengthy amounts of gameplay from a young age amongst the more experienced videogame players.

Boot et al.'s (2008) claim that extensive videogame experience may be a prerequisite for significant improvements in performance has implications for researchers and practitioners, as much of the literature around the effects of videogame experience only examines the recent level of videogame use without examining gameplay earlier in life. Studies investigating the effects of videogame experience typically define videogame experience by the levels of videogame use within the six to twelve months prior to the study (McKinley et al., 2011 ; Vallett et al., 2013; Green et al., 2012; Dye et al., 2009; Baniqued et al., 2013). As a result, the full impact of extensive videogame use may not be taken into

account, particularly exposure during childhood years when videogame use tends to be more intensive and frequent than during adulthood (Greenberg et al., 2010).

Individual factors affecting the transfer of training

In a review of the transfer of training literature, Grossman and Salas (2006) noted that the outcomes of training studies can often be inconsistent, and that one cause for these inconsistencies may be due to differences in the individual capabilities of learners. This proposition is corroborated by Ackerman (2014), commenting on the expertise literature, who suggests that the development of the heightened performance, which defines expertise, results from an interchange between experience and individual ability. Therefore, while experience within the domain may be a necessary condition to performing at an expert level, it is not sufficient to explain expert-level performance (Loveday, Wiggins, Harris, O'Hare & Smith, 2013a; Ackerman, 2014). The role of individual ability and the transfer of training is most notably observed with cognitive ability.

In a meta-analysis of factors influencing the transfer of training, Blume et al. (2010) reported that cognitive ability was the strongest single predictor of the transfer of training. Further, the relationship between cognitive ability and the transfer of training was strongest when the trained skills were highly adaptable across different contexts and problems, such as 'building rapport' or 'developing a presentation'. Grossman and Salas (2011) suggest as an explanation, that higher levels of cognitive ability enhance the learner's capacity to internalise and employ the knowledge and skills gained during training. Therefore, it appears that individual factors amongst learners, such as cognitive ability or personality, may play a significant role in the degree to which skills can be transferred from one learning environment to another context.

Summary and the present study

The existing literature suggests that videogame experience is associated with heightened performance in other tasks, indicating that a transfer of learning is likely to occur in related contexts (Gopher et al., 1994; Rosser et al., 2007). One possible avenue is that action videogame experience enhances processing speed, which results in a greater capacity to monitor, encode, and respond to large amounts of information (Green and Bavelier, 2003; Wilms et al., 2013; Vallett et al., 2013). There is also considerable evidence to suggest that videogame use, and particularly with action videogames, is associated with perceptual learning, which heightens the individuals' perceptual abilities and their performance during tasks with similar perceptual demands (Green et al., 2010a). The transfer of training literature suggests that this learning is likely moderated by individual factors, with greater cognitive ability (Blume et al., 2010) and frequent and consistent videogame use over a lifetime (Ericsson & Charness, 1994; Boot et al., 2008) likely to lead to higher performance in related tasks.

The present study was designed to determine whether self-rated videogame experience is associated with performance during the initial stage of learning to operate a line-of-sight UAV, and the impact of cognitive ability on this relationship. It was hypothesised that:

1. Higher levels of recent videogame use would be positively associated with the acquisition of skills for operating a line-of-sight UAV, as measured by the achievement of at least five consecutive trials within fifteen consecutive attempts during the Take-off trials and Landing trials, and by performance during the Test Flight trials.
2. A stronger correlation was expected between videogame experience and the acquisition of skills operating a line-of-sight UAV when experience was measured as

accumulated experience playing videogames over the lifetime, rather than as recent experience.

3. Accumulated experience playing action videogames would be a stronger predictor of the acquisition of skills operating a line-of-sight UAV in comparison to non-action videogame experience.
4. Cognitive ability would moderate the relationship between videogame experience and the acquisition of skills operating a line-of-sight UAV, with higher cognitive ability associated with greater levels of transfer.
5. Processing speed would partially mediate the relationship between action videogame experience and the acquisition of skills operating a line-of-sight UAV, with higher levels of action videogame experience associated with faster processing speeds.

Method

Participants

Forty-one participants were recruited from the Macquarie University undergraduate student population, in return for course credit or $10. Twenty-three males and 18 females completed the study. The mean age of the participants was 21 (*SD* = 4.98). All of the participants reported a high degree of familiarity with using computers, with 93% using a computer every day and the remainder using computers most days of the week. All participants had corrected to normal vision.

A summary of the reported experience playing videogames is provided in Figure 1. The average participant recently played videogames on all platform types once per week, with 46% of participants playing videogames most days of the week and 63% playing at least once per week. The mean frequency of recent videogame use was slightly lower than during childhood and teenage years, with 78% of participants reporting playing at least once per week as teenagers and children.

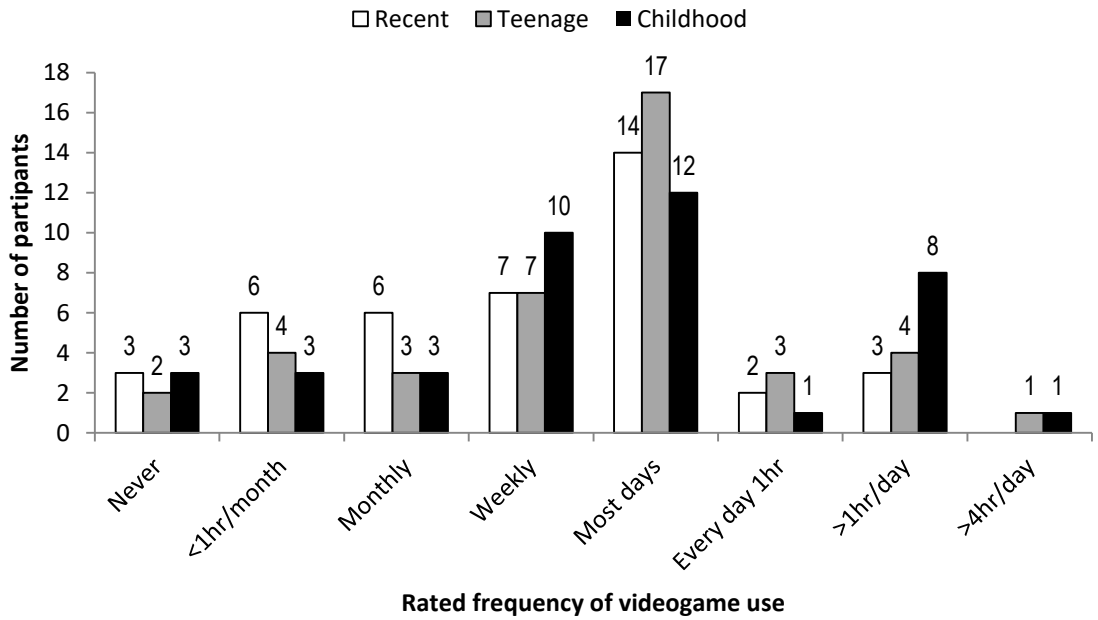

Figure 1. Frequency of self-reports of videogame use by participants across the three life-periods under investigation; recent use, teenage, childhood.

Materials

Survey of videogame experience

For the purposes of the study, a survey was developed that was designed to establish subjective estimates of videogame play (e.g. monthly, weekly, daily) across all types of videogames, as well as individual genres of videogames, recently, during childhood, and their teenage years. Videogame genres were determined based on a modified version of the typology developed by Lucas and Sherry (2004) (see Table 1), with participants being provided a description of the genre and some popular games within that category of game. A consolidated measure of lifetime experience was created by summing the ratings of experience across all three life stages.

Measures of ability

To determine whether cognitive ability moderates the relationship between videogame experience and performance in the UAV flight tasks, the participants completed the Raven's Standard Progressive Matrices (Raven, Raven & Court, 1998), a non-verbal measure of general mental ability. The Standard Progressive Matrices has demonstrated a .71 correlation with the full IQ score of the WAIS-IV and has been associated with educative ability and occupational success (Raven et al., 1998). The Standard Progressive Matrices involves the participants completing abstract visual patterns, and due to time-constraints was conducted with a 10 minute time limit in the present study. The use of a 10 minute administration time, rather than the typical 20 minutes, has been successfully employed by other empirical research (Felvus, 1989; Creed, Wiener & Creed, 1999; Creed, 1999).

Visual processing speed was measured using the WAIS-IV Processing Speed Index (Wechsler, 2008). The Processing Speed Index is a pencil & paper test, comprising two sub-tests: Symbol Search which involves participants finding one of two target symbols from a

symbol array; and Coding in which participants recode a series of numbers into symbols. Both sub-tests are timed, with participants having two minutes to complete each sub-test.

Table 1

Genres of videogames included in the survey of videogame experience with popular examples from the genre.

Genre	Description	Examples
Real-time Strategy	Games that use strategic planning skills under time pressure	*Total War series; Age of Empires; StarCraft*
Puzzle	Games where there is a problem that can be solved without reliance on chance	*Tetris; Portal*
Role playing game / Fantasy	Games that let you assume a character role	*Diablo; Elder Scrolls; Final Fantasy*
Action / adventure	Complex games that involve action elements (e.g. shooting & fighting) in which you go on an adventure	*Grand Theft Auto; Resident Evil; Zelda*
Sports	Games based on athletic teams and events	*FIFA Soccer; Tony Hawk*
World Simulation	Games where you create and manage a simulated world	*Civilisation, The Sims; Sim City; Farmville*
Vehicle simulator / Racing	Games that focus on controlling a vehicle	*Hawxs; Need for Speed*
First person shooter	Games where you have a first person perspective and shoot other characters	*Call of Duty; Counterstrike; Medal of Honour*
Fighter	Games that focus on martial arts or hand-to-hand combat	*Mortal Combat, Tekkan, Street Fighter*
Arcade	Simple games requiring speed and dexterity, browser games	*Angry Birds; Tetris; Super Mario Brothers*
Parlour games	Computer versions of ‘old-time favourites’, including board and card games	*Solitaire; Chess; Sodoku*

UAV flight simulator

Real Flight 6.0™ is a commercially available UAV simulator for recreational and industry training of line-of-sight UAV flight skills, and was used as the simulator in the study. The simulated aircraft is controlled using an industry standard remote controller, which incorporates two joysticks that control the speed and direction of the aircraft. For the purposes of the present study, the fixed-position line-of-sight version was used, as this is closest to the existing demands within many of the commercially available civilian UAVs in Australia where the pilot must operate the aircraft using line-of-sight, rather than a 'point of view' display. The simulator was displayed on a 40 inch monitor, with the participants being seated two metres from the screen.

Procedure

Ethics approval was granted for the below stated methodology by Macquarie University's Human Research Ethics Committee for Human Sciences and Humanities.

Participants completed the videogame experience survey on Qualtrics, a web-hosted survey platform. They also completed the paper and pencil version of the Standard Progressive Matrices and the Processing Speed Index. Following the completion of these tasks, the participants were introduced to the UAV simulator, with a basic explanation of the controls and what was expected of them during the task. The participants completed three flight tasks; a series take-offs (Take-off Trials), a series of landings (Landing Trials), and a task that involved a take-off, completion of a circuit of the airfield, and landing that, in combination, comprised the UAV Test Flight Trials. For each set of trials, participants were instructed to complete as many successful repetitions as possible in the ten minutes provided. A time period was used, rather than a fixed number of trials, as this would ensure that participants received a similar amount of time across all three tasks, thereby controlling for the impact of fatigue.

In the first series of trials, the Take-off trials, participants were asked to perform take-offs from the runway while remaining within the confines of a space marked by clearly visible boundaries. Transgression over these boundaries resulted in an unsuccessful trial, with the aircraft disintegrating and being reset to the initial position. To complete the second series of trials, the Landing trials, participants were asked to land an incoming aircraft on the runway within the marked boundaries. Consistent with Take-off trials, crossing the boundary resulted in an unsuccessful task with the aircraft being reset to the initial position. In the final task, the Test Flight Trials, participants conducted a short flight around the runway area including taking-off, an aerial circuit of the runway and then, a landing. In all three phases, the participants' viewpoint was fixed in a single position, as illustrated in Figure 2.

The order of the UAV flight tasks was fixed since, during pilot testing, participants indicated that the Take-off trials was easier than the Landing trials, which was, in turn, easier than the Test Flight trials. Therefore, from a learning perspective, it appeared reasonable to progress from easier to more difficult tasks, and this remained consistent for all participants. For each of the UAV flight trials, participants were asked to complete as many successful repetitions as possible in the 10 minutes provided. The measure of interest for the Take-off and Landing trials was the achievement of consistent performance to demonstrate the acquisition of skilled performance. As a result, performance during the Take-off and Landing trials was calculated as the number of trials required to attain five consecutive successful repetitions, calculated as a proportion of the total number of trials undertaken by a participant. As the Test Flight trials were considerably difficult to complete successfully, performance in this case was measured by accumulated points for progressing through each stage of the trial, as a proportion of the overall number of attempts. An ascending score was applied to the successful completion of each segment (e.g. successful take-off, successfully beginning the circuit) as depicted in Figure 2. The maximum possible performance score was

6.00 which would represent successfully carrying out the take-off, circuit, and landing in every attempt.

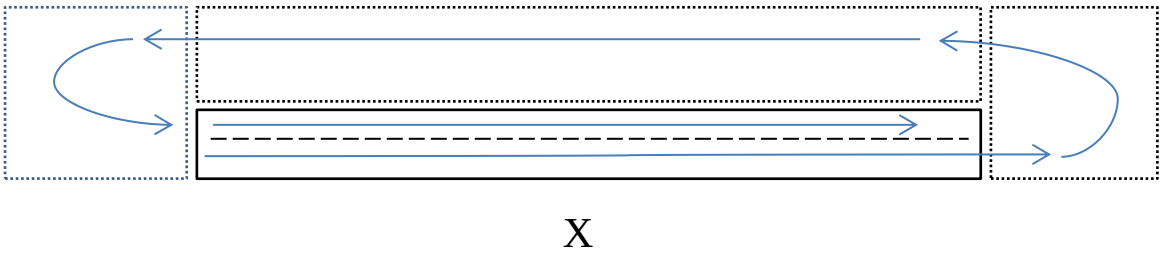

Figure 2. Flightpath in Test Flight trials. Arrow heads indicate completion of sections and where points are gained during the task. The X marks the fixed viewpoint position of the participants during the task.

Results

Videogame experience data

Videogame use was recorded using the frequency of use ratings displayed in Figure 1 across three life-periods, child, teen, and recent use. The mean rating for each videogame genre is displayed in Table 2. These data were summed across the three life phases to create an overall measure of accumulated experience in the genre. A confirmatory factor analysis was conducted on these accumulated experience scores to determine whether experience in the ten different videogame genres clustered around two distinct factors, action and non-action videogame experience, as suggested by Cohen et al. (2007) and Green et al. (2010a). Variables were extracted using a principal components analysis with varimax rotation, with factors requiring an Eigen value over 1.

Table 2.

Descriptive statistics of self-reports of videogame experience across the three life-periods across 11 videogame genres. Means use is average of the frequency ratings displayed in Figure 1.

Game genre	Recent use		Child		Teenage	
	M	*SD*	*M*	*SD*	*M*	*SD*
First-person shooter	2.78	1.89	2.73	2.06	3.95	2.26
Adventure	2.61	1.41	3.20	1.95	3.78	1.92
RPG	2.37	2.05	2.54	1.98	3.27	2.26
Vehicle	2.10	0.94	3.05	1.64	2.73	1.38
Sport	1.95	1.52	1.98	1.29	2.46	1.69
Real-time strategy	2.20	1.54	2.63	1.84	2.73	1.96
Fighter	1.73	1.00	2.44	1.60	2.44	1.50
Parlour games	2.46	1.36	2.77	1.47	2.90	1.26
Puzzle	2.80	1.38	2.54	1.36	3.17	1.32
World simulator/turn-based strategy	2.34	1.67	2.93	1.84	3.22	1.94
Arcade	2.46	1.43	3.20	1.71	3.29	1.62

The results of the principle components analysis suggested that individual videogame experience could best be understood by two factors as illustrated in Table 3. The videogames in the first factor conformed to Green et al.'s (2010a) definition of action videogames (i.e. fast pace; rapid identification of targets, rapid planning, unpredictable, high demands on attention and visual scanning), while those in factor two related less to these dimensions. Consequently, the first factor was labelled action videogame experience while the second factor was labelled non-action videogame experience. The results of the principle components analysis suggest that there is a differentiation between action and non-action videogames, and that individual preferences can be differentiated between these two forms of videogame.

Table 3.

Eigenvalues resulting from the Rotated Component Matrix for videogame experience genres. The results suggest that videogame experience tends to cluster around two factors.

Game genre	Action videogame experience	Non-action videogame experience
First-person shooter	.889	.004
Adventure	.880	.133
RPG	.778	.030
Vehicle	.739	.077
Sport	.733	-.170
Real-time strategy	.729	.272
Fighter	.662	.060
Parlour games	-.234	.835
Puzzle	.055	.835
World simulator/turn-based strategy	.090	.748
Arcade	.441	.742

Data Normality

Participants attempted a mean 72.7 trials in the Take-off Trials (*SD*=17.440) in the 10 minute time limit, of which 58.1% (*SD* = 31.90) were completed successfully. The data pertaining to successfully completed trials in the Take-off trials were not normally distributed and displayed a bimodal distribution (Shapiro-Wilk (40) = 0.830, $p < 0.0005$), although kurtosis and skewness were within acceptable ranges (skewness = 0.523, *S.E.* skewness = 0.369; kurtosis = -1.358, *S.E.* kurtosis = 0.724).

The participants completed a mean 50.6 (*SD* = 15.188) trials in the Landing Trials, of which 53.59% (*SD* = 29.25) were successful. While the landing performance was non-normal with a bimodal distribution (Shapiro-Wilk (40) .890, $p = 0.001$), skewness and kurtosis were within acceptable ranges (skewness = 0.321, *S.E.* skewness = 0.369; kurtosis = -1.352, *S.E.* kurtosis = 0.724).

As both the Take-off and Landing data were non-normal, these measures were transformed into binary measures as to whether or not the participant was able to successfully complete five consecutive trials within the first fifteen attempts. The transformed measures

for the Take-off trials yielded 19 cases where the participants succeeded in achieving five consecutive trials and 22 cases where participants were unsuccessful, with participants typically being able to meet the performance criteria of completing five consecutive trials after a mean 42.0% of trials (*SD* = 38.90). Using the same approach for the Landing data, 25 cases were recorded where participants achieved the performance criterion, while 16 cases were unsuccessful, with participants typically being able to meet the performance criteria of completing five consecutive trials after a mean 50.3% of trials (*SD* = 34.31).

Performance during the Test Flight trials was calculated by allocating a score for each section of the flight task that the participants completed without crashing (see Figure 2), including taking off, turning the aircraft, conducting a circuit of the runway, turning the aircraft into a landing position, landing the aircraft on the runway, and bringing the aircraft to a stop. The distribution of trial attempts is displayed in Table 4, indicating that the majority of attempts did not surpass Stage 3. Participants completed a mean 30.29 attempts (*SD* = 13.473) in the 10 minutes time allocated (*SD* = 13.473). The transformed flight scores were normally distributed (Shapiro-Wilk (40) .991, *p* = 0.986) with an acceptable level of skewness (skewness = 0.083, *S.E.* skewness = 0.369) and kurtosis (kurtosis = 0.047, *S.E.* kurtosis = 0.724).

Table 4.

Frequency of progress of through each of the stages in the Test Flight trials. Values note the frequency of trials that reached each stage in the task.

Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Success	Total
150	342	456	240	34	20	1242
12.1%	27.5%	36.7%	19.3%	2.7%	1.6%	100%

Approach to analyses

Due to the non-normal data for the Take-off and Landing trials, a stepwise binary-logistic regression was used, with the performance criteria of achieving five consecutive successful trials within fifteen attempts used as the dependent variable. The analyses for the Take-off data are displayed in Table 5, with the analyses of the Landing data displayed in Table 6. The Test Flight trials data were analysed using a step-wise series of ANOVA regressions with random effects, and critical alpha set to 0.05. The linear regression analyses of the Test Flight trials data are displayed in Table 7. Six models were examined across each of the three UAV tasks to test the hypothesised relationships between videogame use and skill acquisition in the UAV flight tasks.

Model 1 relates to the first hypothesis examining the association between recent reports of videogame use and included the self-reported measure of recent videogame use as the lone predictor variable. Model 2 was designed to test the second hypothesis comparing recent videogame use and accumulated videogame experience in predicting performance on the UAV trials, and included the self-reported measure of recent videogame use and the overall measure of accumulated videogame experience as predictor variables. Model 3 tested the third hypothesis, comparing action videogame experience and non-action videogame experience in predicting performance in the UAV tasks, using the action videogame experience and non-action videogame experience variables developed in the principle components analysis as the predictor variables. Finally, Models 4 and 5 were designed to test the fourth hypothesis, with Model 4 testing the role of cognitive ability as a main effect alongside the measure of action videogame experience, and Model 5 testing the interaction between cognitive ability and the measure of action videogame experience, using the results of the Standard Progressive Matrices as the measure of cognitive ability. Finally, Model 6

examined the fifth hypothesis that processing speed would play a mediating role in the relationship between action videogame experience and performance in the UAV tasks with the results of the WAIS-IV Processing Speed Index as the measure of processing speed.

Videogame experience

The hypothesis that recent levels of videogame use would be associated with higher performance in the acquisition of UAV flight skills was tested across the three tasks using Model 1 of the aforementioned analyses. For Take-off trials (Table 5) a statistically significant, positive relationship was evident between recent videogame use and the likelihood of reaching the performance criteria. Similarly, a statistically significant, positive relationship was evident between recent videogame use and performance in the Test Flight trials (Table 7). This indicates that greater levels of recent exposure to videogames is associated with higher performance in the Take-off trials and the Test Flight trials. By contrast, no statistically significant relationship was evident between recent videogame use and likelihood of reaching the performance criteria in the Landing trials (Table 6).

Table 5.

Likelihood of reaching the performance criteria for the Take-off trials, being the completion of five consecutive take-offs within fifteen attempts, across the six models.

Model	χ^2 goodness of fit	Nagelkerke R^2	Independent variables	Parameter Estimate	*SE*
Model 1	9.407**	0.274	Recent use	0.697*	0.263
Model 2	15.362***	0.417	Recent use	0.544	0.283
			Cumulative experience	0.034*	0.015
Model 3	13.219**	0.368	Action videogame experience	0.059**	0.020
			Non-action videogame experience	0.013	0.030
Model 4	14.484**	0.398	Action videogame experience	0.063**	0.021
			Cognitive ability	0.085	0.074
Model 5	16.062**	0.433	Action videogame experience	0.064**	0.022
			Cognitive ability	0.074	0.074
			Action videogame experience X Cognitive ability	0.005	0.004
Model 6	13.059**	0.364	Action videogame experience	0.060**	0.020
			Processing Speed	-0.450	3.384

$p < 0.05$ = *, $p < 0.005$ = **, $p < 0.0005$ = ***

The hypothesis that accumulated videogame experience would explain a greater proportion of the variance in UAV flight performance compared to recent videogame use was tested using Model 2. A statistically significant, positive relationship was evident between accumulated videogame experience and performance in both the Take-off (Table 5) and Test Flight trials (Table 7). There was no statistically significant relationship between recent experience and performance evident in either task. This suggests that, in comparison to recent levels of exposure, accumulated exposure to videogames over the lifetime is more closely associated with performance in the Take-off trials and Test Flight trials. Consistent with the results arising from Model 1, no statistically significant relationship was evident for the Landing trials (Table 6), with no significant association found between accumulated videogame experience and the likelihood of reaching the performance criteria. This indicates that while exposure to, and experience using, videogames is associated with performance during the Take-off and Test Flight trials, this relationship is not consistent for the Landing trials.

Table 6.

Likelihood of reaching the performance criteria for the Landing trials, being the completion of five consecutive landings within fifteen attempts, across the six models.

Model	χ^2 goodness of fit	Nagelkerke R^2	Independent variables	Parameter Estimate	*SE*
Model 1	0.000	0.000	Recent use	0.000	0.199
Model 2	2.109	0.068	Recent use	-0.136	0.229
			Cumulative experience	0.018	0.012
Model 3	2.832	0.090	Action videogame experience	0.024	0.015
			Non-action videogame experience	-0.008	0.029
Model 4	4.684	0.146	Action videogame experience	0.024	0.015
			Cognitive ability	-0.084	0.062
Model 5	5.563	0.172	Action videogame experience	0.022	0.015
			Cognitive ability	-0.097	0.066
			Action videogame experience X Cognitive ability	0.003	0.003
Model 6	7.750*	0.234	Action videogame experience	0.028	0.016
			Processing Speed	-7.696	3.755

$p < 0.05$ = *, $p < 0.005$ = **, $p < 0.0005$ = ***

The hypothesis that action videogame experience, in isolation, would be associated with UAV flight performance, was tested using Model 3 across the three series of trials. A positive, statistically significant relationship was evident between action videogame experience and successful performance in the Take-off trials (Table 5) and the Test Flight trials (Table 7). However, there was no statistically significant relationship evident between non-action videogame experience in either the Take-off or Test Flight trials. There were no significant relationships evident between either action or non-action videogame experience and performance on the Landing trials (Table 6). This suggests that, only action videogame experience is associated with skill acquisition in the Take-off and Test Flight trials.

Table 7.

Results of the regression analyses of performance in the Test Flight trials across the six models.

Model	ANOVA	R^2	Independent variables	*B*
Model 1	$F(1,39) = 5.942$, $p = 0.019$	0.132	Recent use	0.364*
Model 2	$F(2,38) = 5.428$, $p = 0.008$	0.222	Recent use Cumulative experience	0.230 0.328*
Model 3	$F(2,38) = 11.600$, $p < 0.0005$	0.379	Action videogame experience Non-action videogame experience	0.619*** -0.229
Model 4	$F(2,38) = 10.092$, $p < 0.0005$	0.347	Action videogame experience Cognitive ability	0.579*** 0.134
Model 5	$F(3,37) = 6.728$, $p = 0.001$	0.353	Action videogame experience Cognitive ability Action videogame experience X Cognitive ability	0.599*** 0.142 -0.081
Model 6	$F(2,38) = 10.092$, $p < 0.0005$	0.331	Action videogame experience Processing Speed	0.576*** -0.041

$p < 0.05$ = *, $p < 0.005$ = **, $p < 0.0005$ = ***

Moderating role of cognitive ability

The hypothesis that cognitive ability would moderate the relationship between action videogame experience and UAV flight performance was tested using Model 4 and Model 5 across the three series of trials. Non-action videogame experience was not included in these models as no statistically significant relationship was evident between non-action videogame experience and performance in any of the test conditions. There was no statistically significant main effect between cognitive ability and successful performance in either the Take-off or Landing trials (Table 5 and 6 respectively), nor the Test Flight trials (Table 7). Further, no statistically significant interaction was evident between action videogame experience and cognitive ability in any of the series of trials (Table 5, 6, and 7). This suggests that cognitive ability, as measured by the Standard Progressive Matrices, does not play a role in the explaining relationship between action videogame experience and skill acquisition in line-of-sight UAV tasks.

The role of processing speed

The expected mediating role of processing speed in the relationship between action videogame experience and UAV flight performance was tested using Model 6 across each of the three series of trials. Processing speed was not significantly associated with performance for neither the Take-off trials (Table 5) nor the Test Flight trials (Table 7), when included in a regression model which included action videogame experience as a predictor variable. While a statistically significant relationship was evident between processing speed and likelihood of reaching the performance criteria for the Landing trials (Table 6), this relationship was a negative association, suggesting that higher processing speed ability may inhibit skill acquisition during the Landing trials. Further, action videogame experience was not related to Processing Speed $F(1,39) = 0.163$, $p = .689$ suggesting that higher levels of action videogame use is not associated with heightened information processing speed. In combination, these

results suggest that processing speed does not mediate the relationship between action videogame experience and skill acquisition in the initial stages of learning to operate a line-of-sight UAV.

Discussion

The primary aim of this study was to determine whether, and to what extent, videogame experience is associated with performance during the initial stages of learning to operate a line-of-sight UAV. A secondary aim was to examine the role of cognitive ability and processing speed in this relationship. It was hypothesised that self-reported recent videogame use would be positively associated with performance in the UAV flight trials and that cumulative videogame experience across a lifetime would be more strongly associated with flight performance in comparison to the recent frequency of videogame use. Further, it was hypothesised that cumulated experience in action video-games (games that feature time-pressure, high levels of visual scanning and tracking of multiple objects, rapid decision-making, and the directing of objects within the game space) would be more predictive of flight performance than non-action videogame experience. As cognitive ability is believed to moderate the transfer of training (Blume et al., 2010), it was expected that cognitive ability would moderate the hypothesised relationship between videogame experience and flight performance. Finally, as exposure to action videogames is thought to increase the speed of information processing (Wilms et al., 2013; Dye et al., 2009), it was expected that processing speed would partially mediate the relationship between action videogame use and flight performance.

Videogame experience

The hypothesis that videogame use, both recent and over the lifetime, would be associated with improved performance during the initial stages of learning to operate a line-of-sight UAV was supported, with a positive relationship evident between videogame experience and performance in two of the three series of flight trials. The positive relationship between recent videogame use and performance affirms McKinley et al.'s (2011) observation that videogame players demonstrate significantly greater performance during the

initial stages of learning to operate a UAV compared to non-videogame players. Further, this result offers support for Barnes et al.'s (2000) proposition that videogame players could present a viable population for recruiting future line-of-sight UAV pilots.

Since accumulated videogame experience accounted for a greater proportion of the variance in UAV flight performance than the variance explained by recent videogame use, it suggests that heightened performance amongst videogame players during the initial stages of learning to operate a UAV may require greater levels of videogame experience than had previously been assumed. As a result, it may be the case that the skills that are developed by videogame use may take a considerable period of time to acquire. This is consistent with Boot et al. (2008) who suggests that short-term exposure to a videogame is unlikely to result in improvements in skilled performance. Further, the data suggests that, when examining the impact of videogame experience, it may be more accurate to measure the individual's experience across a lifetime, rather than recent experience. The importance of experience during youth has been highlighted by Ericsson and Charness (1994), who claim that regular practice during one's youth provides a foundation for future performance.

If it is the case that considerable videogame experience, over years and possibly from youth, is needed to effect a transfer of learning, then deploying videogame technology as a training tool could be complicated by the lengthy timeframes required. While some research has demonstrated higher perceptual performance following short exposure to videogames, these were in discreet, highly controlled tasks (Feng et al., 2007; Green & Bavelier, 2003; Green & Bavelier, 2006). Further, the magnitude of the effects was never measured in terms of real-world behaviours, which tend to be more complex. Instead, the tasks used in these studies were relatively simple and controlled experimentally. As a result, while the present study does suggest that videogame experience is associated with higher performance in other tasks, it also suggests that this may require many years of experience to occur. As a result, the

inclusion of videogames within training programs, as suggested by Barnes et al. (2000), may need to take a longer term perspective that involves regular exposure to videogames over longer timespans than has previously been thought.

Type of videogame experience and UAV flight performance

The hypothesis that only action videogame experience would predict UAV flight performance was supported for two of the three series of trials, suggesting that it is only action videogame use that is associated with skill acquisition during the series of UAV trials. In both the Take-off trials and the Test Flight trials, action videogame experience was positively associated with performance in the task, while no significant relationship was evident between non-action videogame experience and task performance. These results are consistent with Cohen et al. (2007) who, following a review of studies examining perceptual performance following exposure to videogame tasks, concluded that only action videogames contain the perceptual and cognitive demands to result in perceptual learning improvements to the player. The results of the present study extend this assertion to more complex tasks than those reviewed by Cohen et al. (2007).

The moderating role of cognitive ability

The hypothesis that cognitive ability would moderate the relationship between videogame experience and UAV flight performance was not supported. Cognitive ability did not affect the relationship between action videogame experience and performance in any of the UAV trials. Therefore, it might be concluded that cognitive ability, as measured by the Standard Progressive Matrices, does not facilitate the transfer of learning from the videogame context to performance during the initial stages of learning to operate a line-of-sight UAV. Further, as no main effect relationships were evident between cognitive ability and flight performance, it can be concluded that cognitive ability, as measured by the Standard

Progressive Matrices, does not significantly affect skill acquisition in the early stages of learning a flight task in a line-of-sight UAV.

The lack of association between cognitive ability and performance contradicts the outcomes of other research where cognitive ability represents an important predictor of performance. For example, following a meta-analysis of 89 training studies, Blume et al. (2010) concluded that cognitive ability was the single greatest predictor of the transfer of training from learning to application. However, Baniqued et al. (2013) has noted that the cognitive and perceptual abilities associated with performance in different videogames varies considerably between tasks, concluding that the differing demands evident between videogames may result in the development of different cognitive and perceptual skills more generally.

The absence of a moderating role of cognitive ability in the relationship between action videogame experience and performance in the UAV tasks suggests that the improved performance associated with action videogames may be primarily due to perceptual learning, which has been linked to extensive action videogame experience (Green et al., 2010a). Perceptual learning tends to be highly context-dependent (Goldstone, 1998) and, as a consequence, the skills developed may be less readily translated to other tasks. Consistent with this perspective, Blume et al. (2010) note that the relationship between cognitive ability and transfer of learning is significantly weaker for ‘closed’ skills, compared to ‘open’ skills which are less context dependent. Since line-of-sight UAV tasks are dependent upon perceptual features, cognitive ability may be less predictive of the transfer of performance in this particular context.

The mediating role of processing speed

The hypothesis that processing speed would play a mediating role in the relationship between videogame performance and learning to operate a UAV was not supported. Processing speed was not related to accumulated action videogame experience, nor was it associated with recent videogame experience. Further, processing speed was not significantly associated with performance in the Test Flight trials.

The absence of a relationship between videogame experience and generalised processing speed suggests that exposure to videogames, and specifically, action videogames, does not significantly improve the information processing speed of the player in other, related tasks. This conflicts with Wilms et al. (2013) and Dye et al. (2009) who suggest that high levels of action videogame experience are associated with superior information encoding ability. Further, processing speed was not positively associated with performance in any of the flight tasks, suggesting that processing speed does not mediate the relationship between videogame experience and learning during the initial stages of learning to operate a UAV.

Implications for research and industry

The present study offers a number of contributions to the existing literature. The proposition that videogame players outperform non-videogame players was supported and as a result, it might be concluded that videogame players may present a useful recruitment population for line-of-sight UAVs, with previous research focusing primarily on vehicles with on-board nose-mounted cameras. Measuring the impact of videogame experience by recent use alone, appears to be inadvisable, with the outcomes of the present study suggesting that examining experience over a lifetime may offer a more accurate predictor of performance. The outcomes of the present study also suggest that short-term exposure to videogames may be insufficient to convey meaningful improvements in performance, and that instead, extended experience may be necessary. The suggestion that only action

videogame experiences are related to higher performance during the initial stages of learning to operate a UAV was supported, with indications that exposure to non-action videogames is not associated with performance in this context. Finally, cognitive ability does not appear to play a significant, moderating role in the relationship between action videogame experience and the initial stages of learning to operate a line-of-sight UAV, nor is it directly associated with the rate of skill acquisition.

A note of caution should be applied in interpreting these findings to avoid the assumption that a class of videogames is ‘process pure’ (Baniqued et al., 2013), and embodies the same demands and develops the same skills or abilities. Instead, individual games can vary considerably in the demands that they place on the player, even within a particular genre. The present study based its determination of ‘action’ and ‘non-action’ videogame experience on the results of a factor analysis, which combined experiences containing certain similarities. However, these games also contain many dissimilarities in the demands placed on the player. This could present a considerable limitation to the present study, as experience in some games within the category could require and develop certain skills more so than other games within that category.

It is of note that the relationships that were observed across the Take-off trials and the Test Flight trials were not evident in the Landing trials. In fact, no significant relationships were evident for any of the measures of videogame experience in the Landing task. A possible reason for this inconsistency is that this task was dissimilar to the other flight tasks. It is possible that this task did not require the rapid reaction speeds nor perceptual abilities which may have underpinned performance in the other flight tasks.

A further limitation of the present study is that it does not contain a measure of videogame performance. The consequence is that high performance in videogames is assumed as a result of high levels of videogame use. It is possible that videogame use does

not necessarily translate to improvements in the underlying skills needed to succeed in the game, meaning that videogame use may not result in similar improvements in performance for all individuals. If the assumption that videogames engage and develop transferable perceptual and cognitive skills is correct, then it would be expected that performance in a videogame that contains demands similar to those evident in a ‘real world’ task would exhibit a relatively greater transfer of training. As a result, future studies should examine the extent to which actual in-game performance is related to performance in other tasks, such as learning to fly a UAV, and whether actual in-game performance offers a more accurate predictor of performance.

Bridging Section

The results of Study 1 provided some support for Triplett's (2008) claim that videogame players make an ideal recruitment population for UAV operations. Consistent with McKinley et al. (2011), higher levels of videogame experience and, in particular with action videogames, was associated with a greater likelihood for success during a series of UAV-related learning tasks. These results suggest that, at least in the early stages of skill acquisition, action videogame players demonstrate a greater proficiency in learning to conduct tasks in a line-of-sight UAV.

A key outcome of Study 1 was the provision of evidence to support a means of identifying a viable recruitment population for UAV operations. Recruitment from this population could present an alternative to relying on experienced pilots, and could go some way towards addressing the current shortfall in candidates in both military and civilian domains (Rose, Arnold & Howse, 2013; U.S. Government Accountability Office, 2014). However, while subjective, self-reports of videogame experience may present a means of identifying prospective UAV operators, these measures are likely to have limited utility in selection.

One reason for the limited utility of self-reports of videogame experience is the difficulty in ensuring the accuracy of responses. In particular, self-reports of experience are prone to bias and misremembering as a result of inaccuracies in memory and social desirability (Brigham et al., 2010; Wood, Griffiths & Eatough, 2004; Fan et al., 2006; Donaldson and Grant-Vallone, 2002). These issues could be compounded by an incentive to misrepresent one's experience to appear more desirable as a candidate (Weiss & Feldman, 2006; Wood, Schmidtke & Decker, 2007). Further, evidence from other domains, such as power control and medicine, indicates that while experience is necessary for skill development it does not necessarily result in high performance (Loveday et al., 2013a;

Loveday, Wiggins, Searle, Festa & Schell, 2013b). As a consequence, alternative, more objective measures are required.

Videogame tasks as a predictor of UAV operator performance

An obvious alternative to relying on subjective measures of videogame experience is to examine actual performance playing action videogames, as this may offer a more objective and reliable indicator of performance. Much of the literature on the impact of videogame exposure in skill development has focused on subjective measures of experience, rather than actual performance. As a consequence, there is limited evidence to suggest a relationship between videogame experience and actual performance in videogames. To date, there is no published research examining whether videogame performance relates to capability during UAV operations. Instead, the available evidence is drawn from studies of laparoscopic surgery.

Rosser et al. (2007) demonstrated that performance in three videogame tasks was positively related to speed and skill amongst experienced surgeons in a simulated laparoscopic surgery task. Further, compared with self-reported experience, videogame performance explained a greater proportion of variance in surgical performance. Similarly, Bardurdeen et al. (2010) also noted that that videogame performance across three games explained a greater proportion of the variance in surgical performance amongst novice surgeons. In combination, these results demonstrate that videogame performance may be a viable means of predicting operator performance, and could prove to be a more accurate measure of subsequent performance in comparison to subjective estimates of experience.

Oei and Patterson (2014) argue that, for there to be a relationship between a videogame task and another task, there needs to be a similarity in task demands. In essence, Oei and Patterson (2014) suggest that commonality in the capabilities required for each task is the underlying basis for the relationship between performance in two or more tasks. This

argument is consistent with Triplett (2008) who suggested that the similarity in capabilities between videogames and UAV operations was what made action videogame players a viable recruitment population.

Evidence to support the association between videogame task performance and performance on related tasks can be drawn from Oei and Patterson (2015) who claim that the development of perceptual skills following exposure to one of four videogames was associated with the demands contained within the task. Similarly, Sims and Mayer (2002) observed that, following 14 hours of exposure to the puzzle game Tetris, mental rotation ability increased, although only for shapes similar to those found within Tetris. While these results suggest that a similarity in demands is evident in explaining a relationship between videogame tasks, this has only been demonstrated in relatively simple tasks. As a result, this assumption needs to be tested in a more complex task, such as UAV operations.

Videogame experience and information processing

While Study 1 demonstrated that action videogame experience is associated with the speed of skill acquisition in a line-of-sight UAV task, it is not clear what underpins this relationship. Improvements to information processing capability, resulting from extensive exposure to action videogames (Connolly et al., 2012) may present a potential explanatory mechanism.

Numerous perceptual and cognitive improvements have been associated with exposure to action videogames including: visual search speed (Green & Bavelier, 2003; Green & Bavelier, 2006); switching of attention (Green & Bavelier, 2003; Strobach et al., 2012); object tracking (Green & Bavelier, 2006); span of visual attention (Green & Bavelier, 2003; Feng et al., 2007); and reaction time (Green & Bavelier, 2003; Strobach et al., 2012; Castel et al., 2005). Drawing on this research, Bavelier et al. (2012) suggest that playing videogames develops the attentional and perceptual resources available to the player, as well

as equipping the player with cognitive frameworks that enable the rapid acquisition and interpretation of visual information in other contexts. If exposure to action videogames does result in heightened information processing capabilities it would be expected that experienced action videogame players would display differences in their acquisition of visual information, which could be observed in their eye-movement behaviours.

Eye-movement behaviours have been demonstrated to differ as a function of experience amongst sports people (Mann et al., 2007) and professionals in domains such as medicine, transportation, security, and cartography (Gegenfurtner et al., 2011; McCarley et al., 2004; Tien et al., 2015; Ooms, Maeyer & Fack, 2014). Meta analyses of eye-movements amongst sports people and professionals (Mann et al., 2007; Gegenfurtner et al., 2011) indicate that ‘experts’ tend to respond to visual information faster and with greater differentiation between relevant and irrelevant information, tending to fixate for longer on task-relevant information and for less time on task irrelevant information. However, there is also evidence to suggest that task demands were related to different patterns of eye-movements. For example, experienced practitioners tended to use fewer fixations of shorter duration during ‘detection tasks’ but not for ‘decision tasks’, despite displaying faster and more accurate responses across both task types (Gegenfurtner et al., 2011). Furthermore, time constrained and dynamic tasks were associated with different patterns to fixed tasks without time pressures. As a consequence, it remains unclear what patterns of eye-movements would be associated with extensive action videogame use.

Study 2

Study 2 is designed to build on the outcomes of Study 1, exploring three questions that resulted from these results. The first of these questions concerns the relationship between performance in action videogames and skill acquisition in learning to operate a line-of-sight UAV, and whether performance, rather than the self-reported measures used in Study 1, can

offer a more accurate predictor of skill acquisition. The second question relates to the role of information processing demands in the transfer of performance from the videogame context to line-of-sight UAV operations, and whether a consistency in task demands is associated with higher levels of association. The third key question is whether there is a relationship between patterns of information acquisition while playing videogames and while conducting tasks in the UAV context.

In addressing these questions, the observations arising from Study 1 were replicated, and specifically the relationship between action videogame experience and performance during a simulated UAV task. Study 2 has been designed to focus on action videogame experience, as no statistically significant relationship was evident between non-action videogame experience and performance on the series of UAV trials. Finally, as no evidence emerged in Study 1 to support the role of cognitive ability and processing speed, both were excluded as variables in Study 2.

Study 2

Alongside the growing popularity of videogames as an entertainment medium has been an increasing research focus on the impact of extensive videogame use on the performance of players (Connolly et al., 2012). Much of this research has focused on action videogames, which are fast-paced and require the player to continually monitor and respond quickly to fast moving targets and rapidly changing events within the game space (Green et al., 2010a). Exposure to these videogames over extended periods appears to be associated with improvements in perceptual and psychomotor skills (Ferguson, 2007; Connolly et al., 2012; Green & Bavelier, 2015). Moreover, these skills acquired during gameplay are associated with greater rates of skill acquisition in related professional tasks, such as operating an Unmanned Aerial Vehicles (UAV) (McKinley et al., 2011), piloting (Gopher et al., 1994), and surgery (Rosser et al., 2007).

The growth of the UAV industry and the need for operators

The relationship between action videogame use and operator performance presents a particular opportunity for the burgeoning UAV industry, which has a pressing need for trained operators (Singer, 2009; U.S. Government Accountability Office, 2014; Rose et al., 2013). The shortfall in skilled UAV operators is especially evident within the military, due to the rapid escalation in UAV operations, the challenging working conditions, and the increasing demand for skilled operators within the civilian sector (U.S. Government Accountability Office, 2014; Poon, 2015).

Historically, experienced pilots of manned aircraft were used to fill UAV operator roles as they were considered to possess many of the flight skills required for UAV operations (Rose et al., 2013; Barnes et al., 2000). However, as UAV operations have expanded, this practice has become unsustainable due to the limited pool of pilots, combined with their dissatisfaction with UAV postings, which were considered less interesting in

comparison to manned flight assignments (Triplett, 2008; Rose et al., 2013; Barnes et al., 2000). As a consequence, distinctive career fields have emerged that are specifically associated with UAV operations, and for which no previous flight experience is required (Rose et al., 2013).

A consequence of this transition towards a separate career path for UAV operators is the need to identify individuals who have the greatest potential as UAV operators. Specifically, there is a need to identify individuals who can quickly and efficiently be trained to satisfy the growing demands for operators. Currently, training as a UAV operator in the US Air Force requires approximately 10 months (U.S. Government Accountability Office, 2014) of a typical three-year deployment (Roth, 2009). The time and the costs associated with training are such that there is a need to ensure that recruits are ideally suited to the role so that training resources are optimised.

Using action videogame players for UAV operations

The potential association between video gaming skills and the skills necessary for successful UAV operations has been recognised for some time. For example, following interviews and task analyses with manned aircraft pilots, UAV operators, and experienced videogame players, Triplett (2008) noted a correspondence in the capabilities required for playing action videogames and those required for UAV operations. These capabilities included problem solving, monitoring information, hand-eye coordination, stress management, concentration, quick responses, communication, and teamwork. As a consequence, Triplett (2008) concluded that videogame players may represent an ideal recruitment population for UAV operators.

Support for Triplett’s proposition is provided by McKinley et al. (2011), who demonstrated that action videogame players outperformed non-action videogame players in learning to land a military-use UAV. Participants who reported playing action videogames

for at least three hours per week in the six months preceding the study demonstrated greater proficiency in three measures critical to safely landing the vehicle, including maintaining the glide slope and controlling the speed and rate of vertical descent. Videogame players also performed at levels similar to qualified pilots in angle detection and targeting tracking when landing a simulated UAV. Although this research is correlational, the results suggest that the skills acquired during action videogames provided a level of capability that could be applied during aspects of UAV operations.

Results, similar to those reported by McKinley et al. (2011), were observed in Study 1 amongst novices during the initial stages of learning to operate a line-of-sight UAV. Self-reported, recent videogame experience was positively related to performance in learning to conduct simple flight tasks using a simulated, line-of-sight UAV. Further, lifetime accumulated action videogame experience explained a relatively greater proportion of the variance in performance over and above recent experience. Consistent with models of learning, these results suggest that, in comparison to periods of limited exposure, access to a learning context over an extended period potentially may provide a stronger basis for the generalisation of skills.

Consistent with McKinley et al. (2011), Rosser et al. (2007) noted that recent exposure to video games was positively associated with operator performance in laparoscopic surgery. Surgeons who self-reported at least 3 hours per week of recent videogame experience tended to outperform non-videogame playing surgeons in their dexterity, coordination, depth perception in a two-dimensional display, and targeting of relevant features. Surgeons who played videogames also completed surgical tasks 24% faster and with 32% fewer errors compared to peers who did not play videogames. Similarly, Shane, Pettitt, Morgenthal and Smith (2008) demonstrated that a history of intense videogame experience, defined as greater than three hours per week, was associated with heightened surgical

performance which was 27% faster and with 37% fewer errors than peers with no history of videogame use. Further, Shane et al. (2008) demonstrated that a history of intense videogame exposure was also associated with a relatively greater rate of skill acquisition, providing further support to the proposition that videogame experience has the potential to enhance cognitive and perceptual abilities that can be applied subsequently to novel tasks.

Action videogames as a means of enhancing cognitive and perceptual capabilities

The association between video game experience and performance on related tasks has generated a level of research interest to identify precisely, the capabilities that are enhanced by video game exposure and the level of exposure necessary to generate improved capabilities. Table 8 summarises the various research initiatives and the capabilities that have been investigated. Similar outcomes are evident in cross-sectional comparisons of experienced action videogame players and non-videogame players (see Table 9). Overall, the outcomes suggest that action videogame experience is associated with improvements across a range of cognitive and perceptual capabilities that relate to the acquisition and processing of task-related information.

Table 8

Summary of videogame training studies demonstrating a causative relationship between action videogame exposure and improvements in cognitive and perceptual capability.

Domain (Task)	Observation	Source
Visual search speed	Action videogame use increases visual search speed	Green & Bavelier (2003)
Switching attention	Action videogame use enhances switching of attention between tasks and performing two concurrent tasks	Green & Bavelier (2003); Strobach et al. (2012)
Tracking multiple objects	Action videogame use increases capacity to track multiple objects under time pressure	Green & Bavelier (2006)
Probabilistic inferences	Exposure to action videogames enhances the ability to process visual and auditory information to make more accurate probabilistic judgements.	Green et al. (2010b)
Spatial attention	Exposure to action videogames increases focused and distributed attention.	Feng et al. (2007); Franceschini et al. (2013)
Mental rotation	Exposure to videogames can increase mental rotation ability.	Feng et al. (2007); Boot et al. (2008); Sims & Mayer (2002)
Increased field of view	Exposure to action videogames enables a wider span of visual attention.	Green & Bavelier (2003); Feng et al. (2007)
Faster reaction speeds	Exposure to action videogames decreases response time to targets.	Green & Bavelier (2003); Strobach et al. (2012)

The need for a similarity in demands for heightened operator performance

Oei and Patterson (2014) argue that the relationship between action videogame experience and performance in other tasks is dependent upon the similarity in the information processing demands imposed by the tasks. For example, 14 hours of exposure to Tetris, a puzzle game where the player rotates shapes to fill-in gaps, is associated with improvements in mental rotation ability, but only for shapes that are similar to those used in Tetris (Sims &

Mayer, 2002). Similarly, Boot et al. (2008) noted that exposure to Tetris only related to increases in mental rotation ability and not to any other capability.

Table 9

Cross-sectional videogame studies, which compare the cognitive and perceptual capabilities of experienced action videogame players with non-videogame players.

Domain	Observation	Source
Visual search speed	Action videogame players conduct faster scans of the visual environment.	Green & Bavelier (2003); Green & Bavelier (2006)
Switching attention	Action videogame players are better able to switch between tasks and are less affected by attentional blink.	Green & Bavelier (2003); Strobach et al. (2012); Boot et al. (2008); Green et al. (2012); Dobrowolski, Hanusz, Sobczyk, Skorko & Waitrow (2015); Cain, Landau & Shimamura (2012)
Reaction speed	Action videogame players have faster response speeds, while maintaining accuracy.	Castel et al. (2005); Dye et al. (2009); Chisholm et al. (2010); McDermott et al. (2014)
Tracking multiple objects	Action videogame players are able to more accurately track and recall multiple objects.	Green & Bavelier (2003); Green & Bavelier (2006); Sungar & Boduroglu (2012)
Change detection	Action videogame players can more accurately identify changes in less time.	Clarke et al. (2011)
Innattentional blindness	Action videogame players are less susceptible to innattentional blindness.	Vallet et al. (2013)
Visual short-term memory	Action videogame players more accurately in recall shapes and colours.	Wilms et al. (2013); Blacker & Curby (2013); McDermott et al. (2014); Sungar & Boduroglu (2012)
Persistence	Videogame players will persist with difficult tasks for longer durations.	Ventura, Shute & Zhao (2013)

To test the relationship between information processing demands and skill generalisation more explicitly, Oei and Patterson (2015) assigned non-video players to one of four game training groups, where each game embodied different levels of five relevant information processing demands: temporal demands, switching of attention, object tracking, selectivity of attention, and visual searching. Following 20 hours of exposure, games that required higher levels of temporal, attentional and object tracking demands resulted in greater levels of corresponding performance compared to exposure to games that embodied lesser temporal, attentional and object tracking demands.

Like Oei and Patterson (2015), Baniqued et al. (2013) proposed that videogames are not 'process pure' experiences which draw uniformly on the same capabilities. Instead, different games require, and thereby enhance, different levels of capabilities (Baniqued et al., 2013). As a result, while action videogames may share many common features, such as temporal demands and visual scanning, individual games present a unique combination of demand types and intensity for the player to overcome. In turn, the differences in these demands enhance different capabilities at different levels. For example, first-person shooter games, which require the player to rapidly scan and respond to the presence of multiple fast-moving targets, are associated with improvements in attention switching, tracking of multiple objects, reaction speeds, and visual scanning (Green & Bavelier, 2006; Strobach et al., 2012; Oei & Patterson, 2015). However, first-person shooter games are not associated with improvements in mental rotation ability (Boot et al., 2008), a demand that does not feature in first-person shooter games.

Predicting operator performance using videogame tasks

Despite the fact that performance improvements are evident following exposure to action video games, much of this evidence is based on subjective estimates of exposure. However, 'exposure' is not necessarily the ideal marker of performance since subjective

estimates can be erroneous and different individuals will experience different rates of skill acquisition per unit exposure. Arguably, it is performance on the video game itself, rather than exposure *per se* that will yield the most reliable predictor of performance, as this performance will demonstrate the capability to respond successfully to the information processing demands which are shared with associated tasks.

Support for this assertion can be drawn from Rosser et al. (2007) who observed that, compared to estimates of video game exposure, a composite measure of videogame performance across three games explained the greatest proportion of the variance in surgical skills. Similarly, after examining the proficiency of 19 medical students' as they learned to complete a series of beginner laparoscopic surgery tasks, Bardurdeen et al. (2010) noted that, while a relationship was evident between videogame experience and laparoscopic surgery performance, scores on three different videogame tasks explained a greater proportion of the variance in the rate at which laparoscopic surgery skills were acquired. Therefore, actual performance in videogames may offer a more explanatory predictor of operator performance in comparison to self-report measures of videogame experience.

The present study

The rapid expansion of UAV operations and the corresponding demand for proficient operators has necessitated the development of new methods to identify trainees who show a propensity for skill acquisition in this context. Importantly, there is evidence to suggest that performance on action videogames may provide a means by which these individuals can be identified (Triplett, 2008; McKinley et al., 2011). Where previous researchers have tended to rely on self-report exposure to videogames, evidence from the domain of laparoscopic surgery in particular, suggests that actual performance in videogame tasks could offer a more accurate and reliable means of assessing capability (Rosser et al., 2007; Bardurdeen et al.

2010). Therefore, the present study is designed to examine whether, compared to self-reported exposure, performance on action videogames explains a greater proportion of the variance in scores during the initial stages of learning to operate a line-of-sight UAV.

To assess the relationship between videogame performance and aptitude in learning to operate a line-of-sight UAV, participants with no prior flight experience underwent a battery of three action videogame tasks, followed by three simulated UAV flight tasks which included a familiarisation component and a Test Flight task. The Test Flight task required the participants to complete a take-off, circuit an airfield, and land the aircraft with performance measured by the mean progress through each stage of the task. University students were selected as an appropriate sample population as they are similar in terms of age, experience, and capability to those targeted for UAV recruitment. Self-report measures of prior videogame experience were also collected. It was hypothesised that self-reported action videogame experience would be positively associated with UAV flight performance, although it was also hypothesised that collectively, video game performance would explain a relatively greater proportion of the variance in UAV flight performance.

To further examine the predictive capability of videogame performance, the present study was designed to establish whether differences in the information processing demands associated with the games differentiated performance during the Test Flight trials. Baniqued et al., (2013) argues that videogames differ considerably in the information processing demands required of the player and, as a result, a stronger relationship would be expected for games where the information processing demands are more consistent with the demands imposed by line-of-sight UAV operations. The three videogame tasks included in this study were selected on the basis that they exemplified different genres of videogames which presented the player with substantially different tasks, the nature of which was expected to

impose different information processing demands upon the player. Table 10 lists the three videogame tasks against the capabilities required for UAV operations (Triplett, 2008). In the context of information processing demands, Call of Duty: Modern Warfare 3™ appears to share the greatest similarity with the Test Flight trials, followed by Total War: Rome 2 ™ , and finally, Flight Control ™ . It was hypothesised that the strength of the association between in-game performance and mean performance in the Test Flight trials would differ between the three games, according to the degree of similarity between the information processing demands associated with each game and the Test Flight trials. As the first-person shooter game shared the greatest similarity with the information processing demands of the Test Flight trials, it was expected to show the strongest relationship between game performance and UAV flight performance, followed by the real-time strategy game, and lastly the arcade game.

Table 10

A priori comparison of the three game tasks against the capabilities required for UAV operations (Triplett, 2008)

Capabilities	Call of Duty (First-person shooter)	Total War: Rome II (Real-time strategy)	Flight Control (Arcade)	Line-of-sight UAV
Decision-making	Moderate	Moderate	Moderate	Moderate
Fatigue management	Moderate	High	Moderate	High
Sustaining situational awareness	High	High	High	High
Problem solving	Low	Moderate	High	Moderate
Monitoring information	Moderate	High	High	Moderate
Sustained attention	High	High	High	High
Planning	Moderate	High	Moderate	Moderate
Directing objects	Moderate	High	High	Moderate
Rapid reaction times	High	Moderate	High	Moderate

Oei and Patterson (2014) assert that the relative correspondence in the information processing demands is the underlying factor which explains the relationship between

exposure to videogames and the propensity for skill acquisition within a particular context. In learning to operate a UAV, this effect is expected to be most evident when the videogame tasks contain a similar level of task demand across the capabilities identified by Triplett (2008). Therefore, it was expected that there would be a stronger relationship between videogame performance and UAV flight performance when there is a greater level of overall similarity in information processing demands between the two tasks.

In the present study, eye tracking was used to consider cognitive processing, since there is evidence to suggest that an association exists between shifts in information processing demands and the frequency of fixations and saccades. For example, meta-analyses of eye-movements in sports people (Mann et al., 2007) and professional tasks (Gegenfurtner et al., 2011) reveal that eye-movement behaviours differ as a function of experience, with ‘experts’ responding more rapidly to presented stimuli, recording more fixations on relevant stimuli for lengthier durations compared to non-experts. Experience may also affect the ability to spread attention across the visual field, with lengthier saccades recorded for experts in comparison to non-experts (Charness et al., 2001). On this basis, the present research was designed to examine whether: (1) a relationship exists between exposure to action videogames and eye-movements, including the mean dispersion of fixations, the mean frequency of saccades, and the mean duration of fixations; and (2) whether a relationship exists between eye movement during videogames and eye movement during the UAV flight task.

Method

Participants

The sample consisted of 53 undergraduate students from Macquarie University, of whom 29 were male and 24 were female, with a mean age of 20.40 (*SD* = 4.179). Participants received course credit for their participation and had corrected-to-normal vision. Self-reported videogame experience across the three life phases is displayed Figure 3.

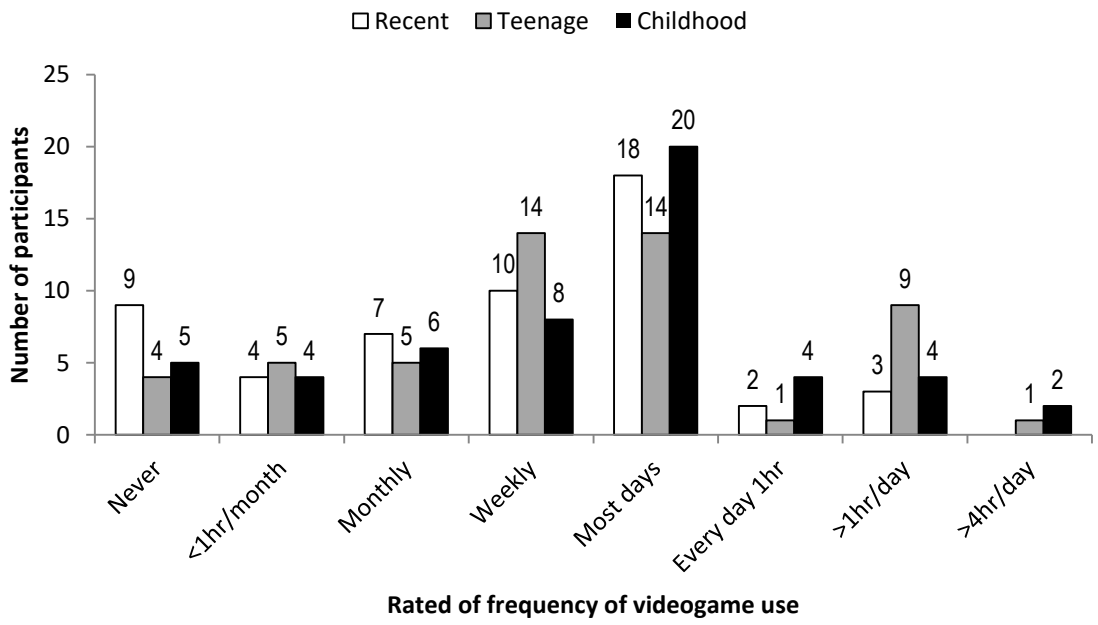

Figure 3. Frequency of self-reports of videogame use by participants across the three life-periods under investigation; recent use, teenage, childhood.

The majority of participants played videogames regularly, with 62% playing videogames at least once per week. In total, 43 % conformed to Green and Bavelier's (2006) classification of a frequent videogame player, playing at least three to four times per week. The self-reported experience reported across each of the genres described by Lucas and Sherry (2004) is displayed in Table 11.

Table 11.

Descriptive statistics of self-reports of videogame experience across the three life-periods in the 11 videogame genres. Mean use is the average of the frequency ratings displayed in Figure 3.

Game genre	Recent use		Child		Teenage	
	M	*SD*	*M*	*SD*	*M*	*SD*
First-person shooter	2.51	1.89	2.42	2.00	3.06	2.08
Adventure	2.55	1.53	3.02	1.91	3.34	1.81
RPG	2.49	1.85	2.02	1.73	2.87	2.04
Vehicle	2.04	1.11	3.23	1.54	2.72	1.34
Sport	2.08	1.65	2.26	1.72	2.47	1.71
Real-time strategy	2.06	1.65	2.09	1.38	2.60	1.92
Fighter	1.66	1.26	2.28	1.70	2.30	1.65
Parlour games	2.36	1.37	2.32	1.47	2.72	1.35
Puzzle	2.43	1.35	2.70	1.49	3.15	1.54
World simulator/turn-based strategy	1.83	1.31	2.68	1.89	2.70	1.72
Arcade	2.30	1.40	3.23	1.84	2.91	1.28

Materials

Videogame tasks

The participants completed three action videogame tasks: a first-person shooter game, Call of Duty Modern Warfare 3™ (COD); a real-time strategy game, Rome Total War 2™ (RTW); and an arcade game, Flight Control™ (FC). The three games were selected because they differed considerably in gameplay, and are popular exemplars of their genre (action video games), with all three achieving game sales above 1 million copies. For each of the videogame tasks, participants first completed an initial practice task to enable them to learn how to play the game, followed by the ‘test trial’. At the completion of each trial, the participant’s score on the task was displayed.

COD is a first person shooter in which the player navigates a three-dimensional environment and attempts to shoot opponents (see Figure 4). Performance in the COD test trial was measured by the number of opponents ‘shot’ before the player was ‘killed’. RTW is a real-time strategy game in which the player commands an army and attempts to outmanoeuvre and defeat an opponent army (see Figure 4). Performance in the RTW ‘test trial’ was measured by the number of the player’s troops remaining at the end of the battle. FC is an arcade style game in which the player directs the flightpath of an increasing number of incoming aircraft to land on a runway, without the planes colliding (see Figure 4). Performance in the FC ‘test trial’ was measured using the number of planes that were landed successfully before two of the planes collided.

Figure 4. Screenshots of from the three videogames (left to right): Call of Duty: Modern Warfare 3; Total War: Rome 2; Flight Control HD.

UAV Simulator

The UAV simulator used in the experiment was Real Flight 7^{TM}, which is a commercially available simulator for recreational and industry training in UAV flight skills. The simulator uses an industry standard remote controller, with two joysticks, to control the speed and direction of the aircraft (see Figure 5). The graphical display was a 60-inch monitor, with participants seated two metres from the screen. Consistent with Study 1, the fixed position line-of-sight visual display and the default fixed-wing aircraft were used for the present study.

Figure 5. Real Flight controller used in the task.

Eye Tracker

Eye-movements were measured using the iView X-HED eye-tracker, developed by SMI Technologies. The eye-tracker operates by targeting an infra-red laser into the participant's eye, with movements of the participant's pupil being registered by an infra-red camera. This allows the changes in the participant's visual scanning to be recorded against a number of key indicators. The eye-tracker captured data at 200 Hz, tracking at less than 0.1 degree with a gaze accuracy of 0.5 degrees.

For the present study, three eye-movement indicators were recorded: mean frequency of saccades, which are rapid shifts in the visual focal point; mean fixation dispersion, which is the spread of fixation points in the visual field; and mean fixation duration, which is the length of time that the participant spends on a particular point in the visual space. These measures were selected as they corresponded to three aspects of perceptual performance highlighted by Mann et al. (2007), Gegenfurtner et al. (2011), and Charness et al. (2001) as being associated with heightened experience, including rapid shifting of attention, measured by saccades per second; wider spread of attention measured by dispersion of fixations; and ability to focus attention on perceptually-relevant information, which was measured using

fixation duration. An object-referent eye-tracker was used for this study, with the camera positioned on a helmet which allowed the participants to move their head during the task.

Measures of experience and information processing demands

Videogame experience was measured using a web-hosted survey based on the videogame experience survey developed in Study 1. Participants rated the frequency of their videogame use recently, during teenage years, and during childhood across a range of videogame genres using Lucas and Sherry's (2004) typology of videogame genres against the frequency of videogame use ratings displayed in Figure 3. Videogame genres were assigned to be either action or non-action videogames, using the results of the factor analysis noted in Study 1. The action and non-action videogame experience measure was then created by summing the experience in each genre across the three age groups.

Information processing demands for the videogame and Test Flight trials were measured using a web-hosted survey, delivered immediately after the completion of each task. The survey was designed to enable participants to rate the subjective level of demand experienced during the task across the nine capability dimensions outlined by Triplett (2008) (see Table 10). Perceived demand was captured along a rating scale of 0-100, with 0 representing no demand and 100 representing a very high level of that demand. The purpose of the demands survey was to compare and validate the *a priori* ratings of the task demands that were presumed to be associated with the videogames.

Procedure

Ethics approval was granted for the below stated methodology by Macquarie University's Human Research Ethics Committee for Human Sciences and Humanities.

Following confirmation of their agreement to participate in the study, the participants completed the survey of demographics and videogame experience. They were subsequently fitted with the eye-tracker, which was calibrated using a standardised visual fixation task,

before commencing the videogame tasks. Prior to each videogame task, participants were given an explanation of the objective of the game and an overview of the controls. They completed two trials of each task, the first of which was a practice trial, and the second a test trial. The order in which the different video games were completed was randomised to reduce learning effects and the impact of fatigue. At the conclusion of each task, the participants completed the post-task survey, which consisted of the survey of the perceived information processing demands.

Following the completion of the videogame tasks, participants were familiarised with the UAV simulator, and were given instructions in the movement of the controls and how to complete the activities prior to each task. Consistent with Study 1, the participants completed two, ten-minute exposure tasks, a take-off and a landing task, where they were asked to complete as many successful attempts as possible within the 10 minute time limit. The purpose of the exposure tasks were to familiarise the participants with the controls and allow practice flying the vehicle before attempting the ‘test trial’. Descriptive statistics for the exposure tasks are displayed in Table 12.

Table 12

Descriptive statistics of exposure task trials displaying mean number of attempts and rates of success in completing the objective of the task.

	M	*SD*	Skew	Skew *SE*	Kurtosis	Kurtosis *SE*
Take-off attempts	64.68	15.69	-.168	.327	-.202	.644
Take-off task % success	57.99	34.22	-.480	.327	-1.355	.644
Landing attempts	41.02	6.11	.341	.327	1.069	.644
Landing task % success	60.11	27.638	-.875	.327	-.239	.644

Following the completion of the familiarisation tasks, the participants were asked to attempt the ‘test trial’, termed the *Test Flight trials*. Consistent with the familiarisation tasks,

participants were given ten minutes to complete as many successful trials as possible. A successful trial consisted of taking-off from the runway, completing a circuit of the airstrip and successfully landing the UAV (see Figure 6.). Since within-subject performance was likely to be variable, participants were given an average score of their progress through the trial, with a point allocated for progress through each stage which accumulated across trials (e.g. successful take-off, achievement of the initial turn) and was then divided by the total number of trials. With six stages in the test trial (see Figure 6), the highest possible score for a single trial was 6.00, representing a successful take-off, circuit and landing.

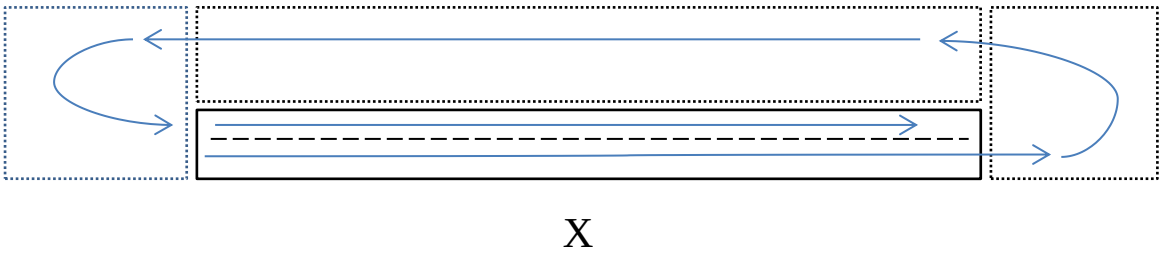

Figure 6. Flightpath in Test Flight trials. Arrow heads indicate completion of sections and where points are gained during the task. The X marks the fixed viewpoint position of the participants during the task.

Results

Flight performance during the Test Flight trials was the mean points accumulated across the trials calculated by the total of the points accumulated divided by the overall number of trials completed in the 10 minute time limit. The frequency of progress through the Test Flight trials is displayed in Table 13. Similar to Study 1 the majority of attempts did not surpass Stage 3.

Table 13.

Frequency of progress of through each of the stages in the Test Flight trials. Values note the frequency of trials that reached each stage in the task.

Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Success	Total
171	504	424	325	34	25	1483
11.5%	34.0%	28.6%	21.9%	2.3%	1.7%	100%

Descriptive statistics of performance in the three UAV tasks are displayed in Table 14. The participants completed a mean 27.98 attempts in the Test Flight trials in the allocated time (*SD* = 11.12) resulting in a mean score of 2.01 (*SD* = 0.87). The Test Flight trials scores were not normally distributed Shapiro-Wilk (52) 0.940, *p* = 0.011). However, the data were within an acceptable range for skewness and kurtosis (skewness = -0.211, *S.E.* skewness = 0.330; kurtosis = -1.268, *S.E.* kurtosis = 0.650).

Table 14

Descriptive statistics of Test Flight trials and videogame performance

	M	*SD*	Skew	Skew *SE*	Kurtosis	Kurtosis *SE*
Test Flight trials	2.01	.868	-.168	.327	-1.312	.644
First-person shooter	12.32	8.559	.533	.327	-1.318	.644
Real-time strategy	715.47	238.99	1.411	.327	4.927	.644
Arcade	8.25	6.765	1.602	.327	3.088	.644

The subjective perceptions of the demands experienced during the videogame and UAV tasks were captured on a rating scale of 0-100, with 100 representing a high level of that stated demand. The mean self-reported information processing demands survey was used to validate the *a priori* categorisation of information processing demands (see Table 10). Low, medium and high rankings were created by dividing the rankings into tertiles, with ratings below 33 equating to a low perceived demand and ratings above 65 being high perceived demand. Using these ratings, the subjective estimates of information processing demands from the participants (Table 15) demonstrates a divergence from the *a priori* estimates across the individual demands and the overall level of perceived demand. The effect of this divergence is that the similarity of mean subjective ratings between the videogame and Test Flight trials present an alternate order of similarity of task demands to the *a priori* rankings, with the arcade game displaying the greatest similarity to the Test Flight trials, while the first-person shooter recorded the lowest overall similarity.

Table 15

Descriptive statistics of reported subjective demands experienced in the videogame tasks and Test Flight trials. Demand score is a rating out of a hundred of perceived task demand, with a higher rating equating a greater level of demand.

	COD			RTW			FC			UAV		
	M	*SD*	Rating	*M*	*SD*	Rating	*M*	*SD*	Rating	*M*	*SD*	Rating
Making decisions	71.34	21.39	High	58.68	23.95	Mod	77.75	18.06	High	60.92	28.47	Mod
Managing tiredness or fatigue	34.13	24.53	Mod	34.36	25.43	Mod	30.83	27.04	Low	59.10	29.44	Mod
Maintaining awareness	76.49	17.59	High	80.53	13.65	Low	87.30	12.40	High	75.94	23.49	High
Solving problems	57.51	23.61	Mod	37.04	24.60	Mod	70.89	19.13	High	57.85	28.06	Mod
Monitoring information	66.66	20.57	High	65.62	19.84	Mod	75.25	21.22	High	67.44	25.93	High
Paying attention	73.72	19.72	High	85.25	12.16	High	87.53	13.54	High	84.98	13.71	High
Planning & strategy	78.89	19.85	High	47.64	23.14	Mod	73.36	19.01	High	58.15	28.92	Mod
Directing objects	80.96	15.77	High	65.21	27.18	Mod	88.98	12.94	High	91.54	13.34	High
Quick reactions	47.66	26.18	Mod	88.75	10.81	High	78.23	17.40	High	73.06	22.97	High
Overall	**60.32**	**12.31**	**Mod**	**63.86**	**14.31**	**Mod**	**72.85**	**11.53**	**High**	**69.44**	**13.84**	**High**

Performance in all three videogames was positively associated with UAV test trial scores (see Table 16). The videogame performance scores and self-reported measure of action videogame experience demonstrated no issues with multicollinearity, suggesting that action videogame experience and performance in the three game tasks represented distinct and separate measures.

Table 16

Correlations between self-reported videogame experience, performance scores, and UAV flight performance

	1	2	3	4	5
1. Action videogame experience		.373*	.303*	.129	.579***
2. First-person shooter	.373*		.161	.019	.441**
3. Real-time strategy	.303*	.161		.232	.435**
4. Arcade	.129	.019	.232		.337*
5. Flight performance	.579***	.441**	.435**	.337*	

$p < 0.05$ = *, $p < 0.005$ = **, $p < 0.0005$ = ***

Action videogame experience and flight performance

The hypothesised relationship between self-reports of accumulated action videogame experience and performance in the Test Flight trials, was tested using Step 1 of a step-wise linear regression, with self-reported experience as the independent variable and flight task performance as the dependent variable with alpha set to 0.05. The results indicate that self-reported, accumulated action videogame experience was positively associated with UAV flight performance in the absence of other variables (see Table 17). This statistically significant, positive relationship suggests that individuals with higher levels of action videogame experience also tended to recorded higher scores on the UAV test trial.

Table 17

Step-wise linear regression of videogame experience and performance on UAV flight performance.

Step	Model	ANOVA	R^2	R^2 change	Independent variables	*B*
1	Experience alone	$F(1,51) = 25.715$, $p < 0.0005$	.335	$\Delta R^2 = .335$, *F change* $(1,51) = 25.716$, $p = <0.005$	Action videogame experience	.579***
2	Experience and performance	$F(4,48) = 12.572$, $p < 0.0005$	.512	$\Delta R^2 = .176$, *F change* $(4,48) = 5.781$, $p = 0.002$	Action videogame experience First-person shooter Real-time strategy Arcade	.386** .257* .223* .231*
3	Performance alone	$F(3,49) = 10.576$, $p < 0.0005$	.393	$\Delta R^2 = .119$, *F change* $(3,49) = 11.659$, $p = 0.001$	First-person shooter Real-time strategy Arcade	.386** .313* .257*

$p < 0.05$ = *, $p < 0.005$ = **, $p < 0.0005$ = ***

Action videogame performance and UAV flight performance

The hypothesis that performance in the three videogame tasks would explain a greater proportion of the variance in UAV flight performance compared to accumulated estimates of action videogame experience was tested using a step-wise linear regression, incorporating subjective estimates of action videogame experience and performance scores in the three videogame tasks as the predictor variables and performance in the Test Flight trials as the dependent variable (see Table 17). The inclusion of the videogame performance scores in the regression resulted in a statistically significant overall model with a significant increase in the variance explained compared to the model which contained action videogame experience in isolation, indicating that the inclusion of performance resulted in a statistically significant increase in the variance explained in UAV test trial scores. The removal of action videogame experience from the model (see Table 17) resulted in a statistically significant decrease in the variance explained in UAV test trial scores. A comparison of variance explained by the performance-alone model (R^2 = .393) with the experience-alone model (R^2 = .335) indicates

that both models account for a similar proportion of the variance in UAV test flight scores, suggesting that videogame performance does not explain a greater proportion of variance in UAV test flight performance than subjective estimates of action videogame experience.

Similarity in information processing demands

The hypothesis that the strength of association between in-game performance and performance in the Test Flight trials would differ according to the degree of similarity in task demands was examined using a series of correlations between the three videogame performance scores and UAV test trial scores. The results indicated there was a difference in the relative strength of the relationship between videogame performance scores and UAV test trial scores (see Table 18). However, when subjected to a Fisher's *Z*-test, no statistically significant difference was evident in the strength of the correlations between each of the videogame scores and UAV flight performance (see Table 18). Therefore, it appears that differences in perceived information processing demands do not significantly affect the relationship between videogame performance and UAV test trial scores.

Table 18

Results of Fisher's Z-test of the correlations between videogame performance and UAV flight performance.

	Fisher's *Z*-test		
	First-person shooter	Real-time strategy	Arcade
First-person shooter		$Z = -0.371$, $p = 0.355$	$Z = -1.186$, $p = 0.118$
Real-time strategy	$Z = -0.371$, $p = 0.355$		$Z = -1.122$, $p = 0.131$
Arcade	$Z = -1.186$, $p = 0.118$	$Z = -1.122$, $p = 0.131$	

Similarity in visual information acquisition

Eye-movement behaviours were captured using the three selected eye-tracking measures; fixation duration (ms), dispersion of fixation, and, saccades per second. These measures were selected to correspond with perceptual performance associated with heightened experience and performance; lengthier durations attending to relevant information, wider spread of attention, and rapid shifting of attention (Mann et al., 2007; Gegenfurtner et al., 2010; Charness et al., 2001). For the purposes of the study, the mean for each measure was used across the task. The descriptive statistics for each of these measures across the four tasks is displayed in Table 19. The fixation duration data for the Test Flight trials was normally distributed, Shapiro-Wilk (42) 0.970, $p = 0.329$, as was the fixation dispersion data, Shapiro-Wilk (42) 0.970, $p = 0.402$. The saccade per second data for the Test Flight trials were normally distributed once two outliers were excluded, Shapiro-Wilk (40) 0.969, $p = 0.338$ (skewness = 0.369, *S.E.* skewness = 0.374; kurtosis = 0.657, *S.E.* kurtosis = 0.733).

A series of bivariate correlations was conducted to determine whether a relationship exists between videogame experience and the eye-movements of participants while playing the videogame tasks and the Test Flight trials, using the three selected eye-movement metrics; fixation dispersion, fixation duration, and frequency of saccades.

Table 19

Descriptive statistics for the three eye-tracking measures across the four tasks

	M	*SD*	Skew	Skew *SE*	Kurtosis	Kurtosis *SE*
UAV test trial fixation dispersion	62.78	13.766	-.533	.365	.183	.717
UAV test trial fixation duration (ms)	1042.07	434.938	.353	.365	-.530	.717
UAV test trial saccades / sec	.6407	.223	.979	.365	1.500	.717
FPS fixation dispersion	72.781	10.285	-.898	.365	.490	.717
FPS fixation duration (ms)	601.695	311.783	1.006	.357	2.271	.702
FPS saccades / sec	1.121	.445	-.458	.357	.434	.702
RTS fixation dispersion	61.909	12.209	-.925	.374	.315	.733
RTS fixation duration / sec	609.347	187.243	.328	.374	.004	.733
RTS saccades / sec	1.073	.389	.420	.374	.320	.733
Arcade fixation dispersion	1.667	.472	-2.169	.357	5.837	.702
Arcade fixation duration / sec	443.934	193.215	1.757	.357	9.896	.702
Arcade saccades / sec	1.494	.479	-1.336	.357	2.745	.702

The correlations suggest that there is an inconsistent relationship between self-reported action videogame experience and eye-movements during videogame tasks, with significant correlations for two of the three videogame tasks but not for the Test Flight trials. Statistically significant, positive correlations were evident between subjective estimates of action videogame experience and fixation dispersion in the first-person shooter $r(42) = .425$, $p = 0.005$ and real-time strategy games $r(40) = .349$, $p = 0.027$. Statistically significant, positive relationships were also evident between action videogame experience and the mean duration of fixations during the first-person shooter game $r(44) = .503$, $p = 0.001$, although not for either the real-time strategy $r(40) = -.087$, $p = 0.593$ nor arcade games $r(44) = .061$, $p = 0.694$. Inconsistent relationships were obtained between subjective estimates of action

videogame experience and frequency of saccades with significant, positive correlations for the real-time strategy game $r(40) = .375$, $p = 0.017$, although no significant relationships were evident for the first-person shooter $r(44) = .052$, $p = 739$ nor for the arcade games $r(44) = .291$, $p = 0.055$.

No significant relationships were evident between subjective estimates of action videogame experience and any of the eye-movement measures during the Test Flight trials; dispersion of fixations $r(42) = .122$, $p = 441$, fixation duration $r(42) = .102$, $p = 0.521$, nor frequency of saccades $r(40) = .181$, $p = 265$. The inconsistent relationships between subjective estimates of action videogame experience and eye-movements measures during the videogame tasks and the Test Flight trials indicates that there is no consistent relationship between exposure to action videogames and changes to information processing, as measured by eye-movements.

The correlations reveal a significant positive relationship between fixation dispersion in each of the three games and the UAV Test Flight trials scores. Significant, positive relationships for fixation dispersions during the videogame task and the Test Flight trials were evident for all three tasks; first-person shooter $r(42) = .406$, $p = 0.008$, real-time strategy $r(40) = .570$, $p < 0.0005$, and arcade $r(42) = .315$, $p = 0.042$. This suggests a degree of correspondence between measures of information processing between the videogame context and UAV operation context.

The fixation duration and saccade frequency measures yielded less consistent relationships between videogame performance and UAV test trial scores. While significant positive correlations were observed for the first-person shooter $r(42) = .364$, $p = 0.018$ and real-time strategy games $r(40) = .420$, $p = 0.007$ for the duration of fixation measure, no significant relationship was evident for the arcade game $r(42) = .085$, $p = 0.591$. Further, a significant relationship was evident between saccade frequency in the Test Flight trials and

the real-time strategy game $r(38) = .378$, $p = 0.019$, although no relationship was evident for either the first-person shooter $r(40) = .129$, $p = 0.427$ or for the arcade game $r(40) = .121$, $p = 0.456$. The lack of consistency in the relationships may indicate that the association between videogame performance and UAV test trials scores was not necessarily explained by a correspondence in information processing. Alternatively, eye-tracking measure may not present an optimal indicator of information processing in this context.

Discussion

The present study

The aim of this study was to determine whether performance on action videogames is associated with performance during the initial stages of learning to control a line-of-sight UAV. This study also sought to examine the extent to which a correspondence in information processing demands explained similarities in levels of performance and information acquisition. Participants' experience playing videogames was measured before they completed three videogame tasks followed by a UAV flight task, referred to as the Test Flight trials. Eye-movements were measured during each of the videogame and Test Flight trials, with measures of information processing demands taken at the conclusion of each task.

A statistically significant, positive relationship provided support for the hypothesised relationship between self-reported action videogame experience and scores on the UAV trial task. These results are consistent with McKinley et al. (2011) and Study 1 where positive relationships were evident between action videogame experience and UAV flight performance. The present study extends these previous investigations by incorporating measures of videogame performance in addition to self-reported measures of experience.

It was hypothesised that videogame performance data would explain a greater proportion of the variance in UAV test trial scores in comparison to self-reported measures of experience. Although the addition of videogame performance data to regression models did explain a greater proportion of the variance in UAV test trial scores in comparison to self-reported experience in isolation, a comparative analysis between the relative predictive capabilities failed to differentiate self-reported experience from videogame performance. Therefore, it appears that the greatest predictive capability is afforded by a model that incorporates self-reported videogame experience and videogame performance, across a number of action video game genres. The fact that performance on the three action

videogames was unrelated suggests that the analysis did not suffer from multicollinearity and that each of the games draws on distinct capabilities, all of which are associated with performance during the initial stages of learning to operate a simulated UAV.

The results did not support the hypothesised role of similarity in information processing demands in explaining the relationship between videogame performance and UAV test trial scores. Specifically, there were no differences evident between performance on the three videogames and the strength of association with the UAV test trial scores. The lack of a significant difference between the three tasks suggests that a greater overall similarity in information processing demands did not result in significantly higher performance when there was less similarity.

The lack of consistency between the information processing demands of the videogame tasks and performance on the UAV test trial contrasts with Oei and Patterson's (2014) assertion that similarities in information processing demands explain differences in the strength of association between performance on tasks. A potential explanation for this inconsistency is that overall similarity in information processing demands does not necessarily relate to an association with task performance. Bavelier et al. (2012) suggest that the features common to all action videogames, such as fast-pace, rapid shifts of attention, and unpredictability, produce substantive differences to the perceptual system of the player. However, it is also possible that it is similarity in specific demands that correspond to a relationship, rather than overall similarity in information processing demands.

The eye-tracking data demonstrated inconsistent relationships across the eye-movements measures between the three videogame tasks, and eye-movements in the Test Flight trials (see Table 20). The pattern of eye tracking suggests that only the dispersion of fixations measure provided a consistent relationship between eye-movements during the videogame tasks and eye movements during the UAV test trial. Less consistent were the

patterns evident for duration of fixations and the frequency of saccades. Similarly, while consistent, significant relationships were evident across all three eye-movement measures for the real-time strategy game, indicating a consistency in patterns of information processing, this was not the case for the first-person shooter nor the arcade game. Inconsistent relationships were also evident between subjective estimates of videogame experience and eye-movements in the different tasks. In particular, the significant associations between eye-movements in the videogame tasks and the Test Flight trials were not necessarily consistent with the relationships observed for self-reported experience, bringing into question the specific relationship between these three variables. However, the presented results are exploratory and further research is required to substantiate the outcomes.

Table 20

Presence of a statistically significant relationship between eye-movement variable in the videogame task and the Test Flight trials.

	Dispersion of fixations	Duration of fixations	Frequency of saccades
First-person shooter	✚	✚	✖
Real-time strategy	✚	✚	✚
Arcade	✚	✖	✖

✚ = significant positive relationship, ✖ = no significant relationship

Implications for research

The observation that accumulated exposure to action videogames over an extended period is associated with greater performance during the initial stages of learning to operate a UAV supports a growing body of evidence which suggests that exposure to action videogames improves the capacity for skill acquisition in some circumstances (as noted in

Tables 8 and 9). However, it also suggests that performance on related videogame tasks adds predictive capacity beyond that provided by estimates of experience alone. This observation corresponds with research in laparoscopic surgery (Rosser et al., 2007; Bardurdeen et al., 2010) which also demonstrates that performance in action videogame tasks predicted operator performance over-and-above that explained by self-reports of experience. However, the results of the present study also demonstrated that, in combination, self-reported experience and actual performance explained a greater proportion of variance in UAV test flight performance than videogame performance alone.

Since both self-reported experience and performance playing action videogames explained the greatest proportion of variance, compared to experience or performance alone, it presents a number of opportunities for further investigation. Only three videogames were used for this study, and therefore, it represents a narrow spectrum of the different capabilities required for UAV operations. The inclusion of additional videogame tasks may provide additional explanatory power which could reduce the variance attributed to self-reported experience. Alternatively, videogame experience may present a unique predictor of performance in the UAV test task, independent of performance in videogame tasks. Further research is required to test these possibilities.

The observation that each of the three videogame tasks was independently associated with UAV flight performance and not associated with one another, suggests that each game required different underlying capabilities for success. This observation is consistent with Baniqued et al. (2013) who observed that different games require different capabilities from the player. It also suggests that no single type of videogame task is associated with operator performance and, as a consequence, multiple game tasks are required to predict operator performance. However, as only three videogames were used in the present study, amongst a plethora of videogame genres and subgenres, further research is required to confirm this

assertion and to identify which types of videogame tasks are most predictive of operator performance.

The inconsistent relationships observed between patterns of visual information acquisition, as measured by eye-movements, between the action videogame tasks and the UAV test task also presents an opportunity for further research. The results demonstrate a consistent relationship between the dispersion of fixations across the game tasks and the UAV test task, indicating that there may be a similarity in information acquisition between videogame tasks and related operator tasks. However, the less consistent results for fixation duration and saccade frequency leaves substantial uncertainty as to the nature and degree to which there is a similarity in information acquisition between the tasks. It is possible that it is only the dispersion of fixations that is reliably associated between videogame play and UAV operations. Alternatively, different games may present different visual demands which would account for the inconsistency in the results. The results of the present study were exploratory in nature and additional research is required to further explore and better understand the relationship between videogame experience, information processing, and operator performance. Future research could also examine whether the relationship between eye-movements in videogame tasks and other tasks relates to differences in both task performance and information processing performance.

Implications for industry

Since performance in three commercially available action videogames predicted performance in learning to operate a line-of-sight UAV, it suggests that action videogame technology does present a viable means of assessing and predicting the performance of non-pilots, at least during the initial stages of learning to operate a line-of-sight UAV. Data relating to each game yielded an independent increase in the variance in flight performance explained suggesting that each game was measuring different, underlying capabilities needed

to learn to operate a UAV. Therefore, multiple game tasks that encapsulate different capabilities required for UAV operations are likely to be needed for future UAV selection assessment tools to fully capture the full range of capabilities required for UAV operations.

The use of videogame tasks as a form of capability assessment has been suggested previously by Rabbitt, Banerji and Szymanski (1989) and Halverson and Owen (2014), who argue that videogame-like assessment tasks could provide an immersive and inherently motivating platform to measure capability. The present study provides support for this suggestion and indicates that commercially available videogames could, in-fact provide an inexpensive means of identifying the likely performance of future UAV operators. However, this study captured a narrow range of UAV flight performance and over a short duration, which limits the ability to determine whether videogame performance is related to UAV operator performance over the longer term. Consequently, further research is required to identify the degree to which videogame tasks can reliably predict operator performance, as well as identifying which games are specifically associated with career success.

Limitations

This study has a number of limitations, the first of which is the restricted selection of game tasks that were used in the study. Potentially, this prevented a broader understanding of those games that are most closely associated with performance in operator tasks. The present study indicates that a broad suite of action videogames is likely to be associated with learning to operate a line-of-sight UAV. Future exploration of a broader array of videogame tasks may identify the set of skills that transfer from videogame tasks to UAV operations, and may establish common features that were not evident in the present study.

A further limitation of this study is the relatively short amount of time that was permitted to establish performance on each videogame task. Potentially, assessing

performance over an extended period may provide a more accurate representation of the skills that are necessary in the acquisition of novel skills, such as learning to operate a UAV.

An associated issue relates to the assessment of performance exclusively during the early stages of learning to operate a UAV. As a result, the present study does not provide evidence to suggest that videogame performance is predictive of operator performance over the longer term. Further research, employing a longitudinal design, may allow for an understanding of the relationship between videogame experience and performance with operator performance across both training and the career path.

Finally, in exploring the relationship between information acquisition patterns in the videogame and UAV tasks, eye-movements were averaged across the task. This is a substantial limitation, as eye-movements may vary both during the task, as well as a function of performance during the task. The design and exploratory nature of the present study prevented a closer examination of this issue, although future research should explore whether there is a consistency in eye-movements throughout the task and whether differences in performance or experience affect this relationship.

General Discussion

The increasing use of Unmanned Aerial Vehicles (UAVs) in both military and civilian contexts has precipitated a growing demand for skilled operators, which is outstripping the current workforce and traditional recruiting populations (Rose et al., 2013; U.S. GAO, 2014; Poon, 2015). As a result, there is a need to identify new sources of recruitment, as well as develop new methods for selecting these individuals. Videogame technology has been proposed as a means of addressing this gap (Triplett, 2008; McKinley et al., 2009). The aim of this thesis was to determine whether there is a relationship between videogame use and the initial stages of learning to operate a line-of-sight UAV. A secondary aim was to examine possible cognitive mechanisms that might explain this relationship. Two studies were conducted to achieve this aim.

The first study sought to establish the relationship between various aspects of videogame experience and learning to operate a line-of-sight UAV, as well as examine the role of cognitive ability and processing speed in the context of this relationship. Participants completed a survey of their experience playing various genres of videogame at different stages of life, together with two tests of ability, cognitive ability and processing speed, before undertaking a series of simulated UAV flight tasks.

The results of Study 1 revealed that, while recent experience was associated with performance in two of the three UAV tasks, accumulated experience over the lifetime, specifically action videogame experience, explained a significantly greater proportion of the variance in flight performance during the UAV tasks. The results failed to establish a significant role for either measure of ability. No significant relationship was evident between flight performance and cognitive ability, either directly or as a moderator of performance, nor was processing speed related to either action videogame use or flight performance.

The second study expanded beyond subjective estimates of experience in isolation, to examine the relationship between demonstrated performance on three action videogame tasks and performance on a UAV test task. The aim was to establish whether demonstrated videogame performance offered a superior predictor of performance during the initial stages of learning to operate a line-of-sight UAV compared to subjective estimates of videogame experience. The second study also considered the role of information processing in the relationship between videogame use and UAV flight performance, including the similarity in information processing demands between the two contexts and aspects of visual information acquisition. Participants in the second study completed a survey of their subjective estimates of experience playing videogames, before completing three action videogame tasks, followed by the Test Flight trials. A survey of perceived demands was completed following each of the videogame and UAV test tasks. Further, patterns of information acquisition were monitored using an eye-tracking device.

The results of Study 2 confirmed the outcomes of Study 1, demonstrating a statistically significant positive relationship between action videogame experience and performance on the Test Flight trials. While a relationship was evident between performance across all three videogame tasks and performance on the Test Flight trials, the overall variance explained by demonstrated performance in the videogame tasks was similar to that explained by subjective estimates of action videogame experience. In combination, a model containing both action videogame experience and performance in the three videogame tasks accounted for the greater proportion of the variance in the initial stages of learning to operate a line-of-sign UAV than either variable alone. The results also indicated that the perceived similarity in information processing demands was not related to the strength of the relationship between each of the videogame tasks and performance on the Test Flight trials. Finally, the eye-movement data presented inconsistent associations between the measures of

subjective experience, eye-movements during the videogame tasks, and eye-movements during the Test Flight trials. While consistent positive associations were evident between the two contexts for the dispersion of fixation data, less consistent relationships were evident for the fixation duration and saccade frequency measures. Similarly, while there was a consistent relationship across all three eye-movements during the real-time strategy game and the Test Flight trials, less consistent relationships were observed for the first-person shooter and arcade games.

Videogame players as a recruitment population for UAV operations

Recent experience as a predictor of UAV flight performance

Triplett (2008) suggested that videogame players could present a viable recruitment population to fill the growing need for skilled UAV operators. This claim was based primarily on an observation that there was considerable similarity in the capabilities required for both contexts. McKinley et al. (2011) demonstrated that videogame players tended to outperform non-videogame players in learning to complete a simulated landing task, as well as performing at a comparative level to experienced pilots who are the preferred recruitment population for UAV operators. Further, there is considerable evidence to suggest that exposure to videogames is associated with heightened performance in other operator roles such as piloting (Gopher et al., 1994) and laparoscopic surgery (Rosser et al., 2007).

In the context of the present research, the results of both studies provide support for Triplett's (2008) claim that videogame players may present a variable recruitment source for UAV operations. The outcomes demonstrate a positive relationship between recent videogame use and performance on a line-of-sight UAV test task. This indicates that, in the initial stages of learning to complete tasks in a line-of-sight UAV, individuals who regularly

play videogames tend to outperform individuals who have had less exposure to playing videogames.

The results arising from the present research also aligns with McKinley et al.'s (2011) observations that videogame players display a greater aptitude in learning to conduct tasks on a UAV. However, the present results extend McKinley et al.'s (2011) findings to line-of-sight UAVs, suggesting that the relationship between action videogame use extends to a range of UAV tasks.

The role of accumulated videogame experience

While McKinley et al. (2011) focused on recent levels of videogame use, as does much of the research into the impact of videogame experience on cognitive and perceptual performance, there is evidence to suggest that the impact of exposure to videogames on the perceptual and cognitive abilities of the player goes beyond recent experience. When comparing experienced videogame players against non-videogame players who were exposed to 21.5 hours of an action videogame, Boot et al. (2008) noted that, while experienced videogame players displayed superiority compared to non-videogame playing control subjects in object tracking, change detection, mental rotation, and attention switching, non-videogame players who received 21.5 hours of exposure displayed no significant difference, suggesting that extended exposure to videogames may be necessary to achieve meaningful improvements to perceptual and cognitive capabilities. Drawing on research in the areas of sport, chess, aviation, and medicine, Ericsson and Charness (1994) argue that extended exposure, typically from an early age, is necessary to develop the underlying cognitive structures that underpin expert-levels of performance. Thus, it was expected that the level of experience playing videogames over a participant's lifetime would provide a stronger, more

encompassing explanation for the variance in UAV flight performance, in comparison to recent levels of videogame use.

The proposition that extensive exposure over a lifetime would better predict performance during the initial stages of learning to operate a line-of-sight UAV was supported, with the sum of accumulated videogame experience from childhood, teenage years, and recent use explaining a significantly greater proportion of the variance in performance in a UAV test task, compared to ratings of recent exposure to videogames. This observation suggests that experience playing videogames over a lifetime is likely to be a more accurate and reliable predictor in learning to operate a line-of-sight UAV than is recent experience.

The observation that accumulated experience offers a stronger predictor of aptitude in skill acquisition in UAV operations provides support for Boot et al. (2008) insofar as short-term exposure is not sufficient to develop the perceptual and cognitive abilities associated with videogame use. Instead, considerable periods of regular exposure may be required.

Action videogame experience and non-action videogame experience

Baniqued et al. (2013) argue that different types of videogames are associated with different cognitive and perceptual abilities. One point of differentiation that was highlighted by Green & Bavelier (2003) is the classification of action and non-action videogames, with many studies indicating that, only action videogames are associated with heightened cognitive and perceptual performance (Cohen et al., 2007; Green et al., 2010a). Achtman et al. (2008) suggest that, only action videogames contain the cognitive and perceptual demands, such as unpredictability, quick reactions, and constant visual scanning, required to develop these capabilities. This differentiation between action and non-action videogames was not explored by Triplett (2008) nor McKinley et al. (2011) who examined experience across all types of videogames. As heightened cognitive and perceptual performance were

suspected to be the underlying reason for the association between exposure to videogames and aptitude in learning to complete the line-of-sight Test Flight trials in the present research, it was expected that, only accumulated action videogame experience would be associated with performance in the UAV test task, with no direct relationship anticipated for non-action videogames.

The hypothesis that action videogame experience would be associated with performance in the UAV test task was supported in both studies, where accumulated action videogame experience was positively associated with performance during the initial stages of learning to operate a simulated line-of-sight UAV. By contrast, no statistically significant relationship was evident between non-action videogame experience and performance in the UAV test task for either study. Therefore, it appears that only experience playing action videogames is related to aptitude in learning to operate a line-of-sight UAV.

The fact that action videogame experience is predictive of aptitude in learning to operate a line-of-sight UAV provides support for Cohen et al. (2007) and Green et al. (2010a) who posit that only action videogames are likely to be associated with improvements to cognitive and perceptual capabilities, capabilities which may underpin performance in both action video games and UAV operations. The results further contribute to McKinley et al. (2011) by indicating that, in examining the role of videogame experience in learning to operate a UAV, a differentiation needs to be made between different types of videogame task. Further, the results suggest that the recruitment of videogame players for UAV operator roles should focus on those individuals who regularly play action videogames.

Contributions to research literature

The results of the two studies demonstrated a consistent association between estimates of accumulated experience and performance on the Test Flight trials. This observation provides three substantive contributions to the literature on the effects of exposure to videogames and performance in other contexts: (1) the role of accumulated exposure to videogame tasks; (2) evidence to suggest that it is only action videogame exposure that is related to skill acquisition in other contexts; and (3) evidence to demonstrate the relationship between action videogame experience in more complex tasks.

The results of Study 1 indicate that accumulated experience playing videogames, specifically action videogames, provides a stronger predictor of performance in other contexts, in this case learning to complete a series of tasks in learning to operate a line-of-sight UAV. This observation contrasts with much of the research concerning the impact of videogame experience on the player, which has tended to focus on recent experience (e.g. Castel et al., 2005; Green & Bavelier, 2003; Green, et al., 2012; Strobach et al., 2012; West, et al., 2008). While it was evident that recent experience playing videogames was associated with higher levels of performance in the flight tasks, the variance explained was subsumed by the accumulated experience of playing action videogames.

Since accumulated experience represented a stronger predictor of performance in the UAV flight tasks than did recent experience, it suggests that consistent, regular exposure over lengthy periods of time may be a necessary to develop the cognitive and perceptual capabilities which underpin performance in the videogame and UAV contexts. These results are consistent with Ericsson and Charness (1994) who suggested that the development of expert levels of performance typically requires extensive and regular exposure to the target task, often from a young age. Further, the results support the observations of Boot et al. (2008) who suggested that limited exposure to videogame tasks may be insufficient to effect

changes to cognitive or perceptual abilities. The results also highlight the possible impact of exposure during childhood, with the implication that experience accumulated during youth may result in longer-term effects than previous research has shown, particularly in the context of learning to operate a line-of-sight UAV. As a consequence, much of the cross-sectional research into the impact of videogame exposure on the player may not capture the extent of the relationship.

The results of Study 1 indicate that it is only action videogame experience, rather than non-action videogame experience, that is associated with skill acquisition in learning to operate a line-of-sight UAV. This observation corresponds to the assertion (Achtman et al., 2008) that action videogame experience alone is associated with improvements in information processing abilities, with no relationship evident for non-action videogames. However, other researchers (Boot et al., 2008; Sims & Mayer, 2002) have reported associations between exposure to non-action videogames and perceptual capability. Baniqued et al. (2013) may present a possible explanation for this inconsistency, noting that videogames differ significantly in their relationship with assessments of ability, suggesting that videogames differ in the capabilities upon which they draw. Therefore, it might be argued that, only the skills associated with action videogames were relevant during the initial stages of learning to operate a line-of-sight UAV.

Videogame technology as a selection tool for UAV operators

Videogame performance and aptitude in learning to conduct a UAV flight task

Rabbitt et al. (1989) and Halverson and Owen (2014) suggest that videogame technology could be used as a means of assessing capabilities across a spectrum of knowledge, skills, and abilities. This argument is echoed by observations in the context of laparoscopic surgery that have demonstrated an association between performance in three videogame tasks, and surgical skill (Rosser et al., 2007; Rosenberg et al., 2005; Bardurdeen

et al., 2010). Drawing on this research, it was expected that demonstrated performance during the three action videogames would be associated with skill acquisition during the initial stages of learning to operate a line-of-sight UAV.

The proposition that videogame performance would be associated with performance in the Test Flight trials in Study 2, and would explain a greater proportion of variance in flight performance compared to action videogame experience received mixed support. The outcomes suggested that performance in all three action videogame tasks was associated independently with performance on the Test Flight trials in Study 2. However, while demonstrated game performance explained a slightly greater proportion of the variance in flight performance than that explained by self-reported action videogame experience alone, the difference was marginal. Instead, a model that contained both measures of performance and self-reported action videogame experience explained a greater proportion of variance in flight performance than either measure in isolation.

It is of note that there was no evidence of multicollinearity between self-reported measures of experience and performance in any of the videogame tasks, indicating that each measure provided a unique contribution to the variance explained in UAV flight performance. As a result, it appears that, while action videogame performance does appear to predict performance during the initial stages of learning to operate a line-of-sight UAV, a combination of experience and performance measures appears to offer the clearest predictor of skill acquisition in line-of-sight UAV operations.

The association between performance on the videogame tasks and the Test Flight trials in Study 2 indicates that videogame technology may have utility as a tool for selecting prospective UAV operators. The statistically significant relationship evident in Study 2 between videogame performance and UAV flight performance across all three videogame tasks is consistent with the observations of Rosser et al. (2007) and Bardurdeen et al. (2010)

who noted a similar relationship between videogame performance and operator performance in the context of laparoscopic surgery. In combination, these results indicate that performance in videogame tasks could be used as a means of assessing the capabilities of prospective operators. Further, the relationship evident in both the laparoscopic surgery context and in UAV operations may extend to other operator domains, presenting a possibility that videogame tasks may also be related to other operator roles. However, unlike Rosser et al. (2007) and Bardurdeen et al. (2010), videogame performance did not explain a substantially greater proportion of the variance in performance compared to self-reported experience.

One explanation for the inconsistency between the outcomes of Study 2 and Rosser et al. (2007) and Bardurdeen et al. (2010) is the measure used for self-reported experience. Study 2, using the measure of experience established in Study 1, captured accumulated experience playing a range of action videogame genres. By contrast, Rosser et al. (2007) and Bardurdeen et al. (2010) captured generic videogame experience, without differentiating action from non-action experience. As a result, the self-reported experience captured in Study 2 may have explained a greater proportion of the variance in operator performance by focusing on more relevant experience, and capturing a more accurate picture of the nature of the individual's videogame playing.

The approach used when selecting games for inclusion in Study 2 was to capture different types of videogames, the effect of which is evident in the lack of a significant relationship between game scores. By contrast, Rosser et al. (2007) and Bardurdeen et al. (2010) selected games on the basis of their similarity to the laparoscopic surgery task. As a result, if games selected more closely targeted the skills needed for line-of-sight UAV operations, then it is possible that the collective measure of videogame performance may have explained a greater proportion of the variance compared to the measure of experience.

A further possibility is that the proportion of variance explained by action videogame experience may have represented skills or capabilities that were not sufficiently present in the three selected game tasks. Therefore, it is possible that the inclusion of additional videogame tasks, or alternative videogames, may have improved the variance explained by the videogame performance measures and thereby reduced the variance accounted for by self-reported experience

Contribution to the literature

Relatively limited research has been undertaken concerning the relationship between performance in videogames and performance in other contexts, with the majority of previous research designs focusing on measures of subjective ratings of experience. Study 2 contributes to the literature by demonstrating that, while a relationship is evident between subjective measures of videogame experience and objective measures of performance in videogame tasks, each appears to provide an independent predictor of performance in other contexts. Further, the results of Study 2 demonstrate that different videogame tasks may be associated with substantially different capabilities, which can affect their ability to predict performance in other contexts.

Since all three videogame tasks were independently associated with skill acquisition in the Test Flight trials, it suggests that a range of videogame tasks might be used to predict performance in other contexts. The three tasks were selected as they represent the diversity of videogame tasks, with each game being a popular exemplar of a different genre. Call of Duty is emblematic of first-person shooter games, while Rome Total War 2 is one of the most popular real-time strategy games in the market, and Flight Control is a popular example of arcade-style games popularised in mobile platforms.

The relationship between the first-person shooter game and UAV performance is consistent with previous research (Green & Bavelier, 2003; Green et al., 2012; Green &

Bavelier, 2006; Feng et al., 2007) which has associated exposure to first-person shooters with heightened perceptual and cognitive abilities at a general level. Similarly, the relationship between performance in the real-time strategy game reflects the available research that uses the less frequently used real-time strategy genre (Basak, Boot, Voss & Kramer, 2008; Dobrowolski et al., 2015) which notes similar relationships to those observed for first-person games. Finally, while inconsistent relationships have been noted between arcade game use and cognitive and perceptual performance (Sims & Mayer, 2002; Boot et al., 2008; Green & Bavelier, 2006; Feng et al., 2007), the present study indicates that arcade games are associated with skill acquisition during the initial stages of learning to operate a line-of-sight UAV.

Factors affecting the transfer of performance from videogames to skill acquisition in the line-of-sight UAV context.

A secondary aim of the research was to investigate the factors that may influence the relationship between the videogame context and skill acquisition in the line-of-sight UAV tasks. Four factors were investigated that were purported to influence the transfer of performance from the videogame context to the rate of skill acquisition in the UAV context. These included the role of cognitive ability as a moderator of the transfer of learning, the role of generalised processing speed as a mediator of the relationship between videogame experience and UAV flight performance, the similarity in perceived task demands as a facilitator of transfer, and the similarity in information acquisition patterns, as measured by aspects of eye tracking.

Cognitive ability as a moderator of the transfer of learning

Cognitive ability has been identified as the strongest predictor of the transfer of learning (Blume et al., 2010). Grossman and Salas (2006) suggest that cognitive ability better enables the transfer of learning between tasks, as heightened cognitive ability enhances an

individual's capacity to identify the areas of similarity and thereby transfer skills. Therefore, it was expected that cognitive ability would moderate the relationship between action videogame experience and skill acquisition in the UAV tasks, with UAV flight performance expected to be greatest when an individual had both higher levels of cognitive ability and higher levels of videogame experience.

The expected role of cognitive ability as a moderator of the transfer of learning from the videogame context to the UAV context was not supported by the results of Study 1. Cognitive ability was not significantly associated with performance in any of the UAV flight tasks, neither as a main effect predictor nor in combination with action videogame experience. This suggests that cognitive ability, as measured by the Raven's Standard Progressive Matrices, may not play a significant role in predicting the rate of skill acquisition in learning to operate a line-of-sight UAV. These results contrast with the conclusions of Blume et al. (2010), who indicated that cognitive ability is the single greatest predictor of the transfer of learning. A possible explanation for this inconsistency may be evident in the nature of the skills transferred.

In the meta-analysis of the transfer of learning literature, Blume et al. (2010) noted that the type of skill being trained affected the moderating effect of cognitive ability on the transfer of learning. While cognitive ability played a substantial moderating role for highly adaptable skills, this moderating role was less evident for highly prescriptive and context-dependent skills. This distinction may be relevant in interpreting the results of Study 1 as Goldstone (1998) suggests that perceptual learning is highly context-dependent. As a consequence, cognitive ability may not have played a moderating role in the transfer of learning between videogame experience and UAV operations because the skills being transferred were more prescriptive and contextually-bound and thus, less influenced by cognitive ability.

Processing speed as a mediator of the transfer of learning

A number of researchers have demonstrated a relationship between videogame use and speed of processing and reaction speeds to visual information (Wilms et al., 2013; McDermott et al., 2014; Dye, Green & Bavelier, 2009), with Dye et al. (2009) suggesting that exposure to action videogames increases the efficiency with which information can be processed by the player. Triplett (2008) identified quick reactions and information processing as essential capabilities for UAV operators. Therefore, it was expected that generalised information processing ability would mediate the relationship between action videogame experience and the rate of skill acquisition in the UAV flight tasks.

The results of Study 1 indicate that processing speed, as measured by the WAIS-IV Processing Speed Index, did not mediate the relationship between action videogame experience and performance on the UAV flight tasks. No significant relationship was evident between action videogame experience and processing speed, nor was processing speed associated with performance in the UAV flight tasks. This observation suggests that processing speed, as measured by the WAIS-IV, does not significantly contribute to explanations of the transfer of learning between the videogame and UAV contexts.

The absence of a relationship between action videogame experience and processing speed conflicts with previous research (Wilms et al., 2013; McDermott et al., 2014; Dye et al., 2009) where a relationship was evident. The results may call into question Dye et al.'s (2009) claim that exposure to action videogames does, in fact, result in improvements in a generalised speed of information processing. Further, the results of Study 1 suggest that generalised processing speed may not necessarily be a required capability for UAV operations, as suggested by Triplett (2008).

Similarity in task demands and the transfer of performance

Oei and Patterson (2014) suggest that, for a transfer of learning to occur from the videogame context to another, there needs to be some similarity between the tasks in the demands imposed on the individual and the corresponding skills needed to overcome these demands. This argument is consistent with Triplett (2008) who noted that similarities between the skills required for videogames and UAV operations underpins the relationship between performance in both tasks. As a result, it was expected that there would be a stronger relationship between performance in the videogame task and Test Flight trials when there was a greater level of similarity in the capabilities required by the two tasks.

The results of Study 2 failed to establish a significant difference between performance in the three videogame tasks, despite there being differences between the three tasks in their perceived degree of similarity with the Test Flight trials. However, as all three game tasks were associated with the Test Flight trials, but not with each other, it is possible that each game was drawing on different skills, all of which were necessary for performance in the Test Flight trials. If this is the case, it is possible that the similarity in task demands would need to be investigated at the task demand level, rather than in terms of overall similarity. Therefore, the results of the present are inconclusive in determining the need for similarity in task demands for there to be a transfer of learning from the videogame context to the UAV flight context.

Videogames and eye-movement behaviour

Green et al. (2010a) and Bavelier et al. (2012) suggest that extensive action videogame use enhances the player's ability to acquire and process information, an ability which is transferred to other task contexts. As a result, it would be expected that videogame experience would be associated with differences in information acquisition, and that there would be a similarity in the patterns of information acquisition between related tasks. Studies

of eye-movements across a variety of contexts (Mann et al., 2007; Gegenfurtner et al., 2011; Charness et al., 2001) indicate that experts display different patterns of eye-movements compared to less experienced individuals, including lengthier fixations on relevant task information, lengthier saccades, and rapid shifting of attention. A research question was posed to investigate the relationship between subjective estimates of action videogame experience and eye-movements, including fixation duration, frequency of saccades, and dispersion of fixations, during the three videogame tasks and the Test Flight trials.

The results of Study 2 present inconsistent relationships between estimates of action videogame experience and eye-movements during the videogame and UAV tasks. While significant correlations were evident between subjective estimates of action videogame experience and two of three eye-movement measures in two of the videogame tasks, specifically, fixation dispersion and fixation duration for the first-person shooter, and fixation dispersion and frequency of saccades for the real-time strategy game, no significant correlations were evident across any of the eye-movement measures for either the arcade game nor the Test Flight trials. The inconsistency in the relationships between action videogame experience and mean eye-movement behaviours conflict with Green et al. (2010a) and Bavelier et al. (2012), who suggest that exposure to action videogames results in a generalised improvement in information processing, which would suggest a consistent difference in patterns of information acquisition across all contexts as a function of action videogame experience.

Oei and Patterson (2014) argue that consistency between information processing demands within videogame tasks and other contexts is a critical element in the transfer of performance between these two contexts. As a consequence, it was expected that there would be a consistency between patterns of information acquisition between the videogame and other related tasks, a line-of-sight UAV in the case of Study 2. However, limitations in the

available literature prevent a clear understanding of what patterns of eye-movements would be indicative of heightened skill in the videogame context. Thus, a research question was posed to investigate whether a relationship exists for specific patterns of eye-movement behaviours displayed during videogame play and eye-movements during the Test Flight trials, specifically fixation duration, frequency of saccades, and dispersion of fixations.

This expected similarity in patterns of information acquisition between the videogames and Test Flight trials was associated with inconsistent support in the eye-movement measures captured in Study 2. While consistent relationships were evident for the real-time strategy game across all three eye-movement measures, less consistent relationships were evident for the other tasks. Similarly, while fixation dispersion was consistently correlated between the videogame and UAV contexts for all three games, correlations for fixation duration and frequency of saccades were only evident in two and one games each. As such, these results suggest that similarity in patterns of information acquisition, as indicated by Oei and Patterson (2014), may not be consistently observed across eye-movement measures, nor across action videogame tasks. Further, the inconsistency in the relationship between the eye-movement behaviours during the videogame tasks and Test Flight trials presents further evidence to suggest that a generalised alteration of patterns of information processing, as suggested by Green et al. (2010a) and Bavelier et al (2012), is unlikely to be the source of the relationship between performance in the videogame and UAV tasks.

While inconsistent, the results of the eye-movement data suggest that there may be a relationship between patterns of information acquisition during videogame play and in related tasks. However, this research design is exploratory in nature and takes a very broad approach to examining eye-movement patterns, using a mean across the task, which may not capture the relationships in sufficient detail. As a consequence, it is not possible to draw meaningful

conclusions from these results. Thus, further research is required to interpret these relationships at a level of finer detail than was possible in the present study.

Broader implications for industry

The results of the present studies, in combination with previous research, suggest that videogame players may present a viable population for recruitment of UAV operators. However, the results indicate that this only applies to action videogame players, rather than videogame players more broadly. This is an important distinction, as this is a narrower population, excluding other popular forms of videogames such as life simulation games like *The Sims* or casual games like *Angry Birds*. The very large numbers of action videogame players (Entertainment Software Association, 2013) will still ensure that there is a large potential recruitment population upon which the industry can draw. However, the singling out of action videogame players for recruitment as UAV operators could have significant implications for the demographics of the industry, particularly given the lower levels of action videogame use amongst females (Greenberg et al., 2010; Breuer, Festl & Quandt, 2014).

In addition to the identification of prospective UAV operators, the present studies suggest that videogame technology could also be used as a means of assessing capabilities. The results of Study 2 indicated that a combination of measures of action videogame experience and action videogame performance explained the greatest proportion of variance in the Test Flight trials. This would suggest that a two-step approach to recruitment and selection of UAV operators could be employed, with measures of action videogame experience identifying the recruiting population, and videogame-like assessment tasks being used to assess these individuals.

The possibility of using videogame tasks as an assessment tool could have major implications for industry presenting a highly immersive and engaging capability-assessment

medium, which could provide assessors with large and highly informative performance data to inform capability levels to a very detailed level (Halverson & Owen, 2014). The potential of videogame technology as an assessment tool offers benefits for the assessment and selection of a range of professional operator roles in addition to UAV operations, including surgeons. This technology could also offer substantial benefits to educators providing an engaging means of training and assessing competency, as well as a way to efficiently identify the source of a learner's poorer performance areas, thereby enabling highly targeted training interventions (Halverson & Owen, 2014).

The indications arising from present study suggest that the benefits of videogame tasks may be highly specific in terms of the cognitive and perceptual processes utilised by the task. This indicates that if videogame technology is used to assess performance, then multiple game-like tasks may be needed to capture the full spectrum of abilities. Further, this provides further possibilities as an assessment tool, potentially allowing for assessment of particular capabilities, and thereby enabling the cognitive ability style assessments suggested by Rabbitt et al. (1989).

This gamification of ability assessments may present a new frontier for psychologists and assessment specialists alike. By isolating the specific cognitive or perceptual processes engaged in a particular game task, it may be possible to design engaging and immersive means of assessing cognitive and perceptual ability in a manner that is superior to traditional forms of assessment, such as pencil and paper tests. However, if videogame technology is to be utilised as an assessment tool, as suggested by Halverson and Owen (2014), then it is imperative that a greater research focus is required to understand which capabilities can be assessed and in using what types of game tasks.

The results of the present study may also have implications for utilising videogame technology as a training tool for UAV operations. Gopher et al. (1994) posited that

videogame technology could provide a valuable training tool. This claim was adopted by other researchers (Connolly et al., 2012) with a growing body of evidence suggesting that videogame technology can be used as a training tool (Triplett, 2008; Badurdeen et al., 2010; Franceschini et al., 2013). The training benefits attributed to videogames include knowledge and skills development, but also perceptual and cognitive abilities (Connolly et al. 2012). While the present studies did not utilise a training design, the results do indicate that lengthy exposure may be necessary for meaningful changes to performance.

The observation that lengthy periods of regular exposure may be required to develop the cognitive and perceptual capabilities believed to underpin the relationship between videogame experience and UAV operator performance, could affect the utility of videogame technology as a training tool. Specifically, this would suggest that, rather than a one-off training exercise, videogame training would need to be consistent to develop and sustain performance gains. This may mean that the primary benefits of a videogame trainer would be to existing videogame players and experienced pilots, rather than as a means of training non-videogame players. As a result, videogame training tools would need to take a longer term perspective, and potentially be used as a supplement to enhance and maintain capabilities of existing operators.

Limitations of the present study and future research

The research presents evidence to suggest a relationship between videogame use and aptitude in learning to operate a UAV, as well as testing potential mechanisms that explain this relationship. However, the methodology employed does contain some substantial limitations.

A major limitation is that, while associations were identified, the cross-sectional design of the two studies prevents the ability to establish causation. While there is a growing body of research that has demonstrated causal relationships between videogame experience and

improvements in a number of different cognitive and perceptual capabilities (Green & Bavelier, 2003; Green & Bavelier, 2006; Franceschini et al., 2013), the evidence is by no means conclusive. Further, the research that has been conducted thus far has focused on particular cognitive capabilities (Green & Bavelier, 2006) or improvements that may not be relevant to operator performance (Franceschini et al., 2013). Therefore, further research is required, using longitudinal designs, to determine causality in the relationships identified in this paper.

The present research relied heavily on self-reported experience in measuring videogame experience. This may have impacted the accuracy of experience, particularly when measuring videogame use during childhood. Future research could employ alternative, more objective measures. One method is drawing on data from game hosting software, such as Steam or X-BOX Live, which records detailed data on the amount of time played and level of performance for individual games. This could offer a rich and more objective source of data than is possible in self-report surveys.

An area that was not fully explored concerned the specific cognitive and perceptual demands that were required for the completion of the videogame and UAV flight tasks. The demands were either assessed subjectively by participants or rated *a priori* by the investigator. There is no evidence to suggest that the perceptions were accurate. Therefore, future research could be oriented towards establishing accurately, the specific cognitive and perceptual demands associated with the different tasks.

The outcome variables in the present study targeted the initial stages of learning to operate a line-of-sight UAV. Clearly, progression beyond this stage of learning potentially engages more complex cognitive processes and these variables need to be identified if video game experience is to be used for purposes of selection in practice. Further, the use of

university students in the present study potentially resulted in a restriction of range in both technical capabilities and cognitive and perceptual abilities.

In addition to the research areas noted thus far, there is a particular need for future research to go beyond the laboratory. The results of the studies contained within this paper, alongside the results of McKinley et al. (2009), present compelling evidence that videogame players may present a viable recruitment population for UAV operations, and that videogame technology could be utilised to select future operators, assess their capabilities, and train them in the perceptual and cognitive capabilities needed to be effective in their roles. However, to date, there is no published research demonstrating that these findings are valid and applicable to industry. As a result, it is imperative that field studies be conducted to build upon and confirm the findings of the present research.

References

Achtman, R. L., Green, C. S., & Bavelier, D. (2008). Video games as a tool to train visual skills. *Restorative Neurology and Neuroscience, 26,* 435-446.

Ackerman, P. L. (2014). Nonsense, common sense, and science of expert performance: Talent and individual differences. *Intelligence, 45,* 6-17. doi: 10.1016/j.intell.2013.04.009

Badurdeen, S., Abdul-Samad, O., Story, G., Wilson, C., Down, S., & Harris, A. (2010). Nintendo Wii video-gaming ability predicts laparoscopic skill. *Surgical Endoscopy, 24,* 1824-1828. doi: 10.1007/s00464-009-0862-z

Baniqued, P. L., Kranz, M.B., Voss, M. W., Lee, H., Cosman, J. D., Severson, J., & Kramer, A. F. (2013). Cognitive training with casual video games: Points to consider. *Frontiers in Psychology, 4,* 1-19. doi: 10.3389/fpsyg.2013.01010

Barnes, M. J., Knapp, B. G., Tillman, B. W., Walters, B. A., & Velicki, D. (2000). *Crew systems analysis of unmanned aerial vehicle (UAV) future job and tasking environments.* (No. ARL-TR-2081). Aberdeen, MD: Army Research Laboratory.

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychology and Aging, 23, 765-777. doi: 10.1037/a0013494

Bavelier, D., Green, C. S., Pouget, A., & Schrater, P. (2012). Brain plasticity through the life span: learning to learn and action video games. *Annual Review of Neuroscience, 35,* 391-416. doi: 10.1146/annurev-neuro-060909-152832.

Blacker, K. J., & Curby, K. M. (2013). Enhanced visual short-term memory in action video game players. *Attention, Perception, & Psychophysics, 75,* 1128-1136. doi: 10.3758/s13414-013-0487-0.

Blume, B. D., Ford, J. K., Baldwin, T. T., & Huang, J. L. (2010). Transfer of training: A meta-analytic review. *Journal of Management, 36,* 1065-1105. doi: 10.1177/0149206309352880

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta Psychologica, 129,* 387-398. doi: 10.1016/j.actpsy.2008.09.005

Breuer, J., Festl, R., & Quandt, T. (2014). Aggression and Preference for First-Person Shooter and Action Games: Data from a large-scale survey of German gamers aged 14 and above. *Communication Research Reports, 31,* 183-196. doi: 10.1080/08824096.2014.907146

Cain, M. S., Landau, A. N., & Shimamura, A. P. (2012). Action video game experience reduces the cost of switching tasks. *Attention, Perception, & Psychophysics, 74,* 641-647. doi: 10.3758/s13414-012-0284-1.

Call of Duty: Modern Warfare 3 [Game]. (2011). Santa Monica, USA: Activision.

Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119,* 217-230.

Charness, N., Reingold, E. M., Pomplun, M., & Stampe, D. M. (2001). The perceptual aspect of skilled performance in chess: Evidence from eye movements. *Memory & Cognition, 29,* 1146-1152.

Charness, N., & Tuffiash, M. (2008). The role of expertise research and human factors in capturing, explaining, and producing superior performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50,* 427-432. doi: 10.1518/001872008X312206

Chiabrando, F., Marenchino, D., Nex, F., Piatti, D., & Rinaudo, F. (2009). UAV systems for photogrammetric recording in archaeological areas: problems, suggestions, and products. *Proceedings of SPIE Europe Remote Sensing 747807*, 747807-747807. doi: 10.1117/12.830412

Chisholm, J. D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception, & Psychophysics, 72,* 667-671. doi: 10.3758/APP.72.3.667

Civil Aviation Safety Authority. (2002). *Unmanned aerial vehicle (UAV) operations, design specification, maintenance and training of human resources.* Canberra, Australia: Civil Aviation Safety Authority.

Clark, K., Fleck, M. S., & Mitroff, S. R. (2011). Enhanced change detection performance reveals improved strategy use in avid action video game players. *Acta Psychologica, 136,* 67-72. doi: 10.1016/j.actpsy.2010.10.003

Clothier, R. A., Palmer, J. L., Walker, R. A., & Fulton, N. L. (2011). Definition of an airworthiness certification framework for civil unmanned aircraft systems. *Safety Science, 49,* 871-885. doi: 10.1016/j.ssci.2011.02.004

Cohen, J. E., Green, C. S., & Bavelier, D. (2007). Training visual attention with video games: Not all games are created equal. In H. O'Neil, R. Perez (Eds.), *Computer games and adult learning* (pp. 205-227). Amsterdam, Netherlands: Elsevier.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59,* 661-686. doi: 10.1016/j.compedu.2012.03.004

Creed, P. A. (1999). Predisposing factors and consequences of occupational status for long-term unemployed youth: A longitudinal examination. *Journal of Adolescence, 22,* 81-93. doi: 10.1006/jado.1998.0202

Creed, P. A., Wiener, K. K., & Creed, P. (1999). Use of the Shipley Institute of Living Scale and the Raven's Standard Progressive Matrices with unemployed populations. *Journal of Applied Health Behaviour, 1,* 22-26.

Culver, K. B. (2014). From battlefield to newsroom: Ethical implications of drone technology in journalism. *Journal of Mass Media Ethics: Exploring Questions of Media Morality, 29,* 52-64. doi: 10.1080/08900523.2013.829679

Darack, E. (2012). UAVs: The New Frontier for Weather Research and Prediction. *Weatherwise, 65,* 20-27. doi: 10.1080/00431672.2012.653935

Dobrowolski. P., Hanusz, K., Sobczyk, B., Skorko, M., & Wiatrow, A. (2015). Cognitive enhancement in video game players: The role of video game genre. *Computers in Human Behavior, 44,* 59-63. doi: 10.1016/j.chb.2014.11.051

Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-report bias in organizational behavior research. *Journal of Business and Psychology, 17,* 245-260. doi: 10.1023/A:1019637632584

Donohue, S. E., Woldorff, M. G., & Mitroff, S. R. (2010). Video game players show more precise multisensory temporal processing abilities. *Attention, Perception, & Psychophysics, 72,* 1120-1129. doi: 10.3758/APP.72.4.1120

Dye, M. W. G., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. *Neuropsychologica, 47,* 1780-1789. doi: 10.1016/j.neuropsychologia.2009.02.002.

Entertainment Software Association (2013). *Essential facts about the computer and video game industry: Sales, demographic and usage data* (Research Report). Retrieved from: http://www.theesa.com/facts/pdfs/esa_ef_2013.pdf

Entertainment Software Association (2015). *Essential facts about the computer and video game industry: Sales, demographic and usage data* (Research Report). Retrieved from http://www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf

Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist, 49,* 725-747. http://dx.doi.org/10.1037/0003-066X.49.8.725

Fan, X., Miller, B. C., Park, K., Winward, B. W., Christensen, M., Grotevant, H. D., & Tai, R. H. (2006). An exploratory study about inaccuracy and invalidity in adolescent self-report surveys. *Field Methods, 18,* 223-244. doi: 10.1177/152822X06289161

Farrington-Darby, T., & Wilson, J. R. (2006). The nature of expertise: A review. *Applied Ergonomics, 37,* 17-32. doi: 10.1016/j.apergo.2005.09.001

Felvus, J. (1989). Standard Progressive Matrices Test: Norms for a 10-minute administration. *Psychological Test Bulletin, 2,* 20-21.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science, 18,* 850-855. doi: 10.1111/j.1467-9280.2007.01990.x

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *Psychiatric Quarterly, 78,* 309-316. doi: 10.1007/s11126-007-9056-9

Flamberg, M., Pike, N., & Woodrick, M. (2014). U.S. gaming, a 360° view: How we play, buy and interact with games in the U.S. *Nielsen*. Retrieved from http://www.nielsen.com/content/dam/nielsenglobal/us/docs/insights/webinars/2015/webinar-us-gaming-a-360-view-april-2015.pdf

Flight Control [Game]. (2010). Tokyo, Japan: Namco.

Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M., & Fascoetti, A. (2013). Action video games make dyslexic children read better. *Current Biology, 23,* 462-466. doi: 10.1016/j.cub.2013.01.044

Gegenfurtner, A., Lehtinen, E., & Saljo, R. (2011). Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking. *Educational Psychology Review, 23*, 523-552. doi: 10.1007/s10648-011-9174-7

Gertler, J. (2012). *U.S. unmanned aerial systems.* Washington DC: Congressional Research Service.

Goldstone, R. L. (1998). Perceptual learning. *Annual Review of Psychology, 49,* 585-612. doi: 10.1146/annurev.psych.49.1.585

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors, 36,* 387-405.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423,* 534-537. doi: 10.1038/ nature01647

Green, C. S., & Bavelier, D. (2006). Enumeration versus multiple object tracking: The case of action video game players. *Cognition, 101,* 217-245. doi: 10.1016/j.cognition.2005.10.004

Green, C. S., & Bavelier, D. (2015). Action video game training for cognitive enhancement. *Current Opinion in Behavioural Sciences, 4,* 103-108. doi: 10.1016/j.cobeha.2015.04.012

Green, C. S., Li, R., & Bavelier, D. (2010a). Perceptual learning during action video game playing. *Topics in Cognitive Science, 2,* 202-216. doi: 10.1111/j.1756-8765.2009.01054.x

Green, C. S., Pouget, A., & Bavelier, D. (2010b). Improved probabilistic inference as a general learning mechanis, with action video games. *Current Biology, 20,* 1573-1579. doi: 10.1016/j.cub.2010.07.040

Green, C. S., Sugarman, M. A., Medford, K., Klobusicky, E., & Bavelier, D. (2012). The effect of action video game experience on task-switching. *Computers in Human Behavior, 28,* 984-994. doi: 10.1016/j.chb.2011.12.020

Greenberg, B. S., Sherry, J., Lachlan, K., Lucas, K., Holmstrom, A. (2010). Orientations to video games among gender and age groups. *Simulation & Gaming, 41,* 238-259. doi: 10.1177/1046878108319930

Grossman, R., & Salas E. (2006). The transfer of training: What really matters. *International Journal of Training and Development, 15,* 103-120.

Grossman, R. & Salas, E. (2011). The transfer of training: What really matters? *International Journal of Training and Development. 15,* 103-120. doi: 10.1111/j.1468-2419.2011.00373.x

Halverson, R., & Owen, V. E. (2014). Game-based assessment: an integrated model for capturing evidence of learning in play. *International Journal of Learning Technology, 9,* 111-138. doi: 10.1504/IJLT.2014.064489

Herwitz, S. R., Johnson, L. F., Dunagan, S. E., Higgins, R. G., Sullivan, D. V., Zheng, J., Lobitz, B. M., Leung, J. G., Gallmeyer, B. A., Aoyagi, M., Slye, R. E., & Brass, J. A. (2004). Imaging from an unmanned aerial vehicle: agricultural surveillance and decision support. *Computers and Electronics in Agriculture, 44,* 49-61. doi: 10.1016/j.compag.2004.02.006

iView xHED [Eye-tracking tool]. (2011). Teltow, Germany: SMI.

Kay, G., Dolgin, D., Wasel, B., Langelier, M., & Hoffman, C. (1999). *Identification of the cognitive, psychomotor, and psychosocial skill demands of uninhabited combat aerial vehicle (UCAV) operators.* Patuxent River, Maryland: Naval Air Warfare Centre Aircraft Division.

Kirkman, M. A. (2013). Deliberate practice, domain-specific expertise, and implications for surgical education in current climes. *Journal of Surgical Education, 70,* 309-317. doi: 10.1016/j.jsurg.2012.11.011

Klein, G. (1998). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.

Loveday, T., Wiggins, M. W., Harris, J. M., O'Hare, D., & Smith, N. (2013a). An objective approach to identifying diagnostic expertise among power system controllers. *Human Factors, 55,* 90-107. doi: 10.1177/0018720812450911

Loveday, T., Wiggins, M. W., Searle, B. J., Festa, M., & Schell, D. (2013b). The capability of static and dynamic features to distinguish competent from genuinely expert practitioners in pediatric diagnosis. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 55,* 125-137. doi: 10.1177/0018720812448475

Lucas, K., & Sherry J. L. (2004). Sex differences in video game play: A communication-based explanation. *Communication Research, 31,* 499-523. doi: 10.1177/0093650204267930

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology, 29,* 457.

McCarley, J. S., Kramer, A. F., Wickens, C. D., Vidoni, E. D., & Boot, W. R. (2004). Visual skills in airport-security screening. *Psychological Science, 15,* 302-306. doi: 10.1111/j.0956-7976.2004.00673.x

McDermott, A. F., Bavelier, D., & Green, C. S. (2014). Memory abilities in action video game players. *Computers in Human Behavior, 34,* 69-78. doi: 10.1016/j.chb.2014.01.018

McGill, P. R., Reisenbichler, K. R., Etchemendy, S. A., Dawe, T. C., & Hobson, B. W. (2011). Aerial surveys and tagging of free-drifting icebergs using an unmanned aerial vehicle (UAV). *Deep Sea Research Part II: Topical Studies in Oceanography*, *58*(11), 1318-1326. doi: 10.1016/j.dsr2.2010.11.007

McKinley, R. A., McIntire, L. K., & Funke, M. A. (2011). Operator selection for unmanned aerial systems: Comparing video game players and pilots. *Aviation, Space, and Environmental Medicine, 82,* 635-642. doi: 10.3357/ASEM.2958.2011

North, J. S., Williams, A. K., Hodges, N., Ward, P., & Ericsson, K. A. (2009). Perceiving patterns in dynamic action sequences: Investigating the process underpinning stimulus recognition and anticipation skill. *Applied Cognitive Psychology, 23,* 878-894.

Nutwell, R. M. (2000). Unmanned air vehicles-coming of age at last. *Air & Space Europe, 2,* 23-25.

Oei, A. C., & Patterson, M. D. (2014). Are videogame training gains specific or general? *Frontiers in systems neuroscience, 8,* 1-9. doi: 10.3389/fnsys.2014.00054

Oei, A. C., & Patterson, M. D. (2015). Enhancing perceptual and attentional skills requires common demands between the action video games and transfer tasks. *Frontiers in Psychology, 6,* 1-11. doi: 10.3389/fpsyg.2015.00113

Ooms, K., De Maeyer, P., & Fack, V. (2014). Study of the attentive behavior of novice and expert map users using eye tracking. *Cartography and Geographic Information Science, 41,* 37-54. doi: 10.1080/15230406.2013.860255

Poon, L. (2015, September 14). Chinese pilots are in high demand for drones. *Citylab.* Retreived from http://www.citylab.com/work/2015/09/as-demand-for-drone-pilots-soars-in-china-training-schools-gain-popularity/405274/

Powers, K. L., Brooks, P. J., Aldrich, N. J., Palladino, M. A., & Alfieri, L. (2013). Effects of video-game play on information processing: A meta-analytic investigation. *Psychonomic Bulletin & Review, 20,* 1055-1079. doi: 10.3758/s13423-013-0418-z.

Rabbitt, P., Banerji, N., & Szymanski, A. (1989). Space Fortress as an IQ test? Predictions of learning and of practised performance in a complex interactive video-game. *Acta Psychologica, 71,* 243-257. doi: 10.1016/0001-6918(89)90011-5

Raven, J. C., Raven, J., & Court, J. H. (1998). *A manual for Raven's Progressive Matrices and Vocabulary Scales.* London: H. K. Lewis.

Real Flight 6.0 [Simulator]. (2011). Urbana, IL: Great Planes Model Manufacturing Company.

Rose, M. R., Arnold, R. D., & Howse, W. R. (2013). Unmanned aircraft systems selection practices: Current research and future directions. *Military Psychology*, *25*(5), 413. doi: 10.1037/mil0000008

Rosenberg, B. H., Landsittel, D., & Averch, T. D. (2005). Can video games be used to predict or improve laparoscopic skills? *Journal of Endourology*, *19*, 372-376. doi: 10.1089/end.2005.19.372

Rosser, J. C., Lynch, P. J., Cuddihy, L., Gentile, D. A., Klonsky, J., & Merrell, R. (2007). The impact of video games on training surgeons in the 21st century. *Archives of Surgery*, *142*(2), 181-186. doi: 10.1001/archsurg.142.2.181

Roth, E. J. (2009). *A Case for Enlisted Unmanned Aerial System Operators*. Montgomery, AL: Air War College Air University.

Schreiber, B. T., Lyon, D. R., Martin, E. L., & Confer, H. A. (2002). *Impact of prior flight experience on learning Predator UAV operator skills*. (Report No AFRL-HE-AZ-TR-2002-0026). Mesa, AZ: Air Force Research Laboratory.

Shane, M. D., Pettitt, B. J., Morgenthal, C. B., & Smith, C. D. (2008). Should surgical novices trade their retractors for joysticks? Videogame experience decreases the time needed to acquire surgical skills. *Surgical Endoscopy*, *22*, 1294-1297. doi: 10.1007/s00464-007-9614-0

Sims, V. K., & Mayer, R. E. (2002). Domain specificity of spatial expertise: The case of video game players. *Applied cognitive psychology*, *16*(1), 97-115. doi: 10.1002/acp.759

Singer, P. W. (2009). *Wired for war: The robotics revolution and conflict in the 21st century.* New York, NY: Penguin Group.

Smeeton, N. J., Ward, P., & Williams, A. M. (2004). Do pattern recognition skills transfer across sports? A preliminary analysis. *Journal of Sports Sciences*, *22*(2), 205-213. doi: 10.1080/02640410310001641494

Strobach, T., Frensch, P. A., & Schubert, T. (2012). Video game practice optimizes executive control skills in dual-task and task switching situations. *Acta Psychologica*, *140*(1), 13-24. doi: 10.1016/j.actpsy.2012.02.001

Sungar, H., & Boduroglu, A. (2012). Action video game players form more detailed representation of objects. *Acta Psychologica*, *139*, 327-334. doi: 10.1016/j.actpsy.2011.12.002

Tien, T., Pucher, P. H., Sodergren, M. H., Sriskandarajah, K., Yang, G. Z., & Darzi, A. (2015). Differences in gaze behaviour of expert and junior surgeons performing open inguinal hernia repair. *Surgical Endoscopy*, *29*, 405-413. doi: 10.1007/s00464-014-3683-7

Total War: Rome II [Game]. 2013. Tokyo, Japan: Sega.

Triplett, J. (2008). *The effects of commercial video game playing: A comparison of skills and abilities for the Predator UAV* (Report No. AFIT/GIR/ENV/08-M22). Ohio: Air Force Institute of Technology.

United States Government Accountability Office. (2014). *Air Force: Actions needed to strengthen management of unmanned aerial system pilots.* Washington, DC, USA: U.S. Government Accountability Office.

United States Air Force. (2005). *The U.S. Air Force remotely piloted aircraft and unmanned aerial vehicle strategic vision.* Lincoln, NB: U.S. Air Force Research.

Urbahs, A., & Jonaite, I. (2013). Features of the use of unmanned aerial vehicles for agriculture applications. *Aviation*, *17*(4), 170-175. doi: 10.3846/16487788.2013.861224

Vallett, D. B., Lamb, R. L., & Annetta, L. A. (2013). The gorilla in the room: The impacts of video-game play on visual attention. *Computers in Human Behaviour, 29,* 2183-2187. doi: 10.1016/j.chb.2013.05.001

Ventura, M., Shute, V., & Zhao, W. (2013). The relationship between video game use and a performance-based measure of persistence. *Computers & Education*, *60*, 52-58. doi: 10.1016/j.compedu.2012.07.003

Waraich, Q. R., Mazzuchi, T. A., Sarkani, S., & Rico, D. F. (2013). Minimizing human factors mishaps in unmanned aircraft systems. *Ergonomics in Design: The Quarterly of Human Factors Applications*, *21*, 25-32. doi: 10.1177/1064804612463215

Watts, A. C., Perry, J. H., Smith, S. E., Burgess, M. A., Wilkinsin, B. E., Szantoi, Z., Ifju, P. G., & Percival, H. F. (2010). Small Unmanned Aerial Systems for low-altitude aerial surveys. *The Journal of Wildlife Management, 74,* 1614-1619. doi: 10.1111/j.1937-2817.2010.tb01292.x

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale – Fourth Edition: Administration and scoring manual.* Pearson: San Antonio, TX.

Weiss, B., & Fledman, R. S. (2006). Looking good and lying to do it: Deception as an impression management strategy in job interviews. *Journal of Applied Social Psychology, 36,* 1070-1086. doi: 10.1111/j.0021-9029.2006.00055.x

West, G. L., Al-Aidroos, N., & Pratt, J. (2013). Action video game experience affects oculomotor performance. *Acta Psychologica, 142,* 38-42. doi: 10.1016/j.actpsy.2011.08.005

Williams, K. W. (2004). *A summary of unmanned aircraft accident / incident data: Human factors implications.* (Report No. DOT/FAA/AM-04/24). Oklahoma City, OK, USA: Civil Aerospace Medical Institute Federal Aviation Administration.

Wilms, I. L., Petersen, A., & Vangkilde, S. (2013). Intensive video gaming improves encoding speed to visual short-term memory in young male adults. *Acta Psychologica, 142,* 108-118. doi: 10.1016/j.actpsy.2012.11.003

Wilson, J. R. (2013, July). UAV roundup 2013. *Aerospace America, 51,* 26-36.

Wood, R. T. A., Griffiths, M. D., Eatough, V. (2004). Online data collection from video game players: Methodological issues. *CyberPsychology & Behavior, 7,* 511-518. doi: 10.1089/cpb.2004.7.511.

Wood, J. L., Schmidtke, J. M., & Decker, D. L. (2007). Lying on job applications: The effects of job relevance, commission, and human resource management experience. *Journal of Business and Psychology, 22,* 1-9. doi: 10.1007/s10869-007-9048-7

Yellon, S. L., & Ford, J. K. (1999). Pursuing a multidimensional view of transfer. *Performance Improvement Quarterly, 12,* 58-78.

Appendix

Demographics information

Age:

Sex:

Computer game experience questionnaire

1. Currently I typically play computer/video games
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played computer/video games
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played computer/video games
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

I answering the following items please refer to the following categories of games:

Genre	Description	Examples
Strategy	Games that use strategic planning skills	*Civilization, Age of Empires, Total War series*
Puzzle	Games where there is problem that can be solved without chance	*Tetris, Portal*
Role playing game / Fantasy	Games that let you assume a character role	*Diablo; Elder Scrolls; Final Fantasy*
Action / adventure	Complex games that involve action elements (e.g. shooting & fighting) in which you go on an adventure	*Grand Theft Auto; Resident Evil; Zelda*
Sports	Games based on athletic teams and events	*FIFA Soccer; Tony Hawk*
World Simulation	Games where you create a simulated world	*The Sims; Sim City; Farmville*
Vehicle simulator / Racing	Games that focus on controlling a vehicle	*Hawxs; Need for Speed*
First person shooter	Games where you have a first person perspective and shoot other characters	*Call of Duty; Counterstrike; FarCry*
Fighter	Games that focus on martial arts or hand-to-hand	*Mortal Combat, Tekkan*
Arcade	Simple games requiring speed and dexterity, browser games	*Angry Birds; Tetris; Super Mario Brothers*
Parlour games	Computer versions of 'old-time favourites', including board and card games	*Solitaire; Chess; Sodoku*

Strategy games

Games that use strategic planning skills

Civilization, Age of Empires, Total War series

1. Currently I typically play this type of game
    - Never

- Less than once a month
- Once a month
- Once a week
- Most days a week
- Every day for less than 1 hour
- Every day for 1-4 hours
- Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Puzzle

Games where there is problem that can be solved without chance

Tetris, Portal

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Role playing game / Fantasy

Games that let you assume a character role

Diablo; Elder Scrolls; Final Fantasy

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month

- Once a month
- Once a week
- Most days a week
- Every day for less than 1 hour
- Every day for 1-4 hours
- Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Action / adventure

Complex games that involve action elements (e.g. shooting & fighting) in which you go on an adventure

Grand Theft Auto; Resident Evil; Zelda

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours

- Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Sports

Games based on athletic teams and events

FIFA Soccer; Tony Hawk

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month

- Once a month
- Once a week
- Most days a week
- Every day for less than 1 hour
- Every day for 1-4 hours
- Every day for more than 4 hours

World Simulation

Games where you create a simulated world

The Sims; Sim City; Farmville

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Vehicle simulator / Racing

Games that focus on controlling a vehicle

Hawxs; Need for Speed

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

First person shooter

Games where you have a first person perspective and shoot other characters

Call of Duty; Counterstrike; FarCry

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Fighter

Games that focus on martial arts or hand-to-hand

Mortal Combat, Tekkan

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour

- Every day for 1-4 hours
- Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Arcade

Simple games requiring speed and dexterity, browser games

Angry Birds; Tetris; Super Mario Brothers

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never

- Less than once a month
- Once a month
- Once a week
- Most days a week
- Every day for less than 1 hour
- Every day for 1-4 hours
- Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Parlour games

Computer versions of ‘old-time favourites’, including board and card games

Solitaire; Chess; Sodoku

1. Currently I typically play this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

2. As a child (6-12) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

3. As a teenager (13-19) I typically played this type of game
    - Never
    - Less than once a month
    - Once a month
    - Once a week
    - Most days a week
    - Every day for less than 1 hour
    - Every day for 1-4 hours
    - Every day for more than 4 hours

Post task demands survey

1. How much experience do you have playing this game series?

No experience Expert

2. How similar was the game to games you usually play?

Not similar at all Very similar

3. Please rate the demands you experienced in the game you just played.

Making decisions

Low demand High demand

Managing tiredness or fatigue

Low demand High demand

Maintaining awareness of what was going on

Low demand High demand

Solving problems

Low demand High demand

Monitoring information

Low demand High demand

Paying attention

Low demand High demand

Planning and strategy

Low demand High demand

Directing objects in the game space

Low demand High demand

Reaction times and quick responses

Low demand High demand
