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Effects of Visual Interaction Methods on Simulated Unmanned Aircraft Operator Situational Awareness

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ABSTRACT

The limited field of view of static egocentric visual displays employed in unmanned aircraft controls introduces the soda straw effect on operators, which significantly affects their ability to capture and maintain situational awareness by not depicting peripheral visual data. The problem with insufficient operator situational awareness is the resulting increased potential for error and oversight during operation of unmanned aircraft, leading to accidents and mishaps costing United States taxpayers between $4 million to $54 million per year. The purpose of this quantitative experimental completely randomized design study was to examine and compare use of dynamic eyepoint to static visual interaction in a simulated stationary egocentric environment to determine which, if any, resulted in higher situational awareness. The theoretical framework for the study established the premise that the amount of visual information available could affect the situational awareness of an operator and that increasing visual information through dynamic eyepoint manipulation may result in higher situational awareness than static visualization. Four experimental dynamic visual interaction methods were examined (analog joystick, head tracker, uninterrupted hat/point of view switch, and incremental hat/point of view switch) and compared to a single static method (the control treatment). The five methods were used in experimental testing with 150 participants to determine if the use of a dynamic eyepoint significantly increased the situational awareness of a user within a stationary egocentric environment, indicating that employing dynamic control would reduce the occurrence or consequences of the soda straw effect. The primary difference between the four dynamic visual interaction methods was their unique manipulation approaches to control the pitch and yaw of the simulated eyepoint. The identification of dynamic visual interaction increasing user SA may lead to the further refinement of human-machine-interface (HMI), teleoperation, and unmanned aircraft control principles, with the pursuit and performance of related research.

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Dr. Brent Terwilliger has been a Software Engineer with Rockwell Collins Simulation & Training Solutions (STS) since 2004. Prior to becoming an engineer, he worked as a Technical Writer/Editor in the defense contracting community. He received a B.S. in Aerospace Studies (2000) and an M.S. in Aeronautical Science (2005) from Embry-Riddle Aeronautical University in Daytona Beach, FL. Brent recently completed the final requirements of a Ph.D. in Business Administration with a specialization in Aviation (conferred May 2012) from Northcentral University in Prescott Valley, AZ.

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INTRODUCTION

Reduced situational awareness (SA) associated with remote unmanned operation limits an operator's ability to perceive the remote environment, leading to potential for confusion, error, loss of equipment, or loss of human life (Cummings, Myers, & Scott, 2006). Unmanned operating environments are sensory deprived compared to manned environments, lacking peripheral vision, auditory cueing, and motion cueing (Cooke, 2008; Tvaryanas, Thompson, & Constable, 2005). The field of view (FOV) of egocentric unmanned visual displays (i.e., interior view outwards) are narrow and do not depict peripheral data, resulting in the occurrence of the soda straw effect (i.e., reduced environmental FOV resulting in diminished perception; Lewis, Wang, Velagapudi, Scerri, & Sycara, 2009).

The onset of the soda straw effect in operators leads to disorientation, loss of SA, reduced hazard recognition, missing operational information, and human error (Lewis et al., 2009). With pilots removed from the actual flight vehicle, SA becomes essential for safe and efficient unmanned operation by reducing the potential for human error (Cooke, 2008; Giordano, Deusch, Lachele, & Bulthoff, 2010). Implementing cost effective SA multipliers has the potential to increase the SA of operators, diminish human error, and reduce the occurrence of unmanned aircraft accidents.

PURPOSE

Dynamic visual interaction represents a method to increase operator perception and SA through expansion of remote operating environment perception (Kadavasal & Oliver, 2007). Previous researchers have examined the use of methods to increase the environmental perception of an operator with mixed results (de Vries, 2001; Kadavasal & Oliver, 2007; Stelzer & Wickens, 2006). These methods included the use of larger screens (Stelzer & Wickens, 2006), augmented imagery (Kadavasal & Oliver, 2007), and dynamic visual interaction (de Vries, 2001). Discerning if the SA values associated with static eyepoint interaction differed from dynamic eyepoint control in an egocentric visual environment represents the major difference between the current research and prior studies.

The primary goal of this study was to determine whether SA associated with a static eyepoint (i.e., conventional body-fixed camera) differed from dynamic interaction methods (i.e., movable camera). The premise was based on the assertion that the amount of available visual information from the control interface affects the SA of an operator (Giordano et al., 2010; Kadavasal & Oliver, 2007; Lewis et al., 2009). The use of a dynamic eyepoint establishes operator SA at the lowest level, freeing cognitive resources to obtain higher-level SA (Van Erp, Duistermaat, Jansen, Groen, & Hoedemaeker, 2006).

The research examination occurred by measuring the ability of experimental test participants to perceive, comprehend, and project (Endsley, 1988) using four dynamic visual interaction methods (analog joystick, head tracker, uninterrupted hat/Point of View (POV) switch, and incremental hat/POV switch) and a static control treatment (conventional stationary body-fixed view) in a simulated remote egocentric environment. The capture of these measures represented a quantifiable metric of user SA within an unmanned vehicle simulation using technology, techniques, and methods associated with gaming, modeling & simulation (M&S), and teleoperation.

The purpose of the research was not to reflect the accurate reproduction of attention loading an operator might be subject to, but instead, to depict the initial effect of dynamic visual interaction on basic human capability relating to SA using low cost technology. The definition, design, and implementation of the four dynamic visual interaction techniques used in the analysis were focused on improving the perception, comprehension, and projection of an operator to increase SA.

METHOD

Choices made by operators using deficient or inaccurate SA represent human error (Sossong, 2006). Deficient choices associated with unmanned vehicle accidents potentially put the operational hardware and assets at risk (Leduc, Rash, & Manning, 2005). A quantitative completely randomized design (CRD) study featuring experimentation was performed to examine the effect enhancing a single aspect of unmanned aircraft control, visual interaction, has on human SA in a setting that generically simulated egocentric viewpoint operation. Through experimentation, it was possible to observe the interplay between the visual interaction methods (static and dynamic) and the SA of the participants (*Participant* Y_{SA}) to identify techniques, methodologies, and concepts to increase the SA of an unmanned aircraft operator.

Participants

A minimum sample size of 30 participants per treatment ($n = 30$; $N = 150$) was selected to ensure a resulting high power value (98%). The selection of participants involved seven qualifying factors: (a) no relationship to administrator/author; (b) ability to see full color spectrum (no colorblind participants); (c) ability to use joystick with right hand; (d) ability to use joystick hat/POV switch with right thumb; (e) ability to move head 22.5 degrees up/down/left/right from center; (f) basic joystick usage/knowledge/experience; and (g) age range between 18 to 34.

Nonprobabilistic purposive sampling was used in the selection of test participants from clusters (i.e., groups samples were drawn from) in central Florida. The test participants were obtained after 50 clusters in central Florida associated with aviation, aerospace, simulation, or gaming, were contacted. Of the 50, five clusters had volunteers willing to participate (Rockwell Collins, Embry-Riddle Aeronautical University, University of Central Florida, Rollins College, and Seminole State College).

The participants were employees, students, or members of the five clusters and were not directly selected or rejected by the test administrator. The first 150 volunteers were accepted as long as they met the selection criteria and testing activity schedule, reducing the potential for issues with subjectivity and reliability of samples. Once selected, the participants were randomly assigned to a visual interaction treatment.

Egocentric Simulated Operation

The visual interaction techniques used in the study were representative of current visual interaction employed in unmanned control (Defense Update, 2009; Raytheon, 2006; Schiebel, 2010), by previous researchers (de Vries, 2001; Drury, Richter, Rackcliffe, & Goodrich, 2006; Giordano et al., 2010; Osborn, 2009; Stelzer & Wickens, 2006), in other fields (FlightGear, 2011), and custom developed by the researcher. Previous researchers examined interactions using several of the techniques (de Vries, 2001; Drury et al., 2006; Giordano et al., 2010; Osborn, 2009; Stelzer & Wickens, 2006). Recent innovations and advancements exhibited a need to reevaluate interactions to determine if change is now observable between static and dynamic visual interactions.

Static Visual Interaction

The static eyepoint interaction technique represents the method observable in the majority of current unmanned vehicles (Jackson, Tisdale, Kamgarpour, Basso, & Hendrick, 2008). It consists of using a fixed, immovable camera assembly (i.e., body fixed camera) mounted directly to the body of the vehicle (Jackson et al., 2008; Southwest Research Institute, 2010). The focus with the static interaction method was on replicating current unmanned aircraft visual interaction functionality, where the eyepoint would remain fixed within the simulated environment and equal to the FOV of the simulated camera (see Figure 1).

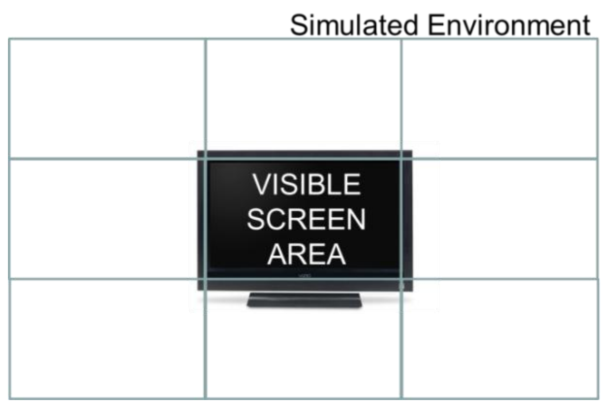

Figure 1. Static View Visible Screen Area in Simulated Environment

Dynamic Visual Interaction

Dynamic visual interaction mitigates the lack of sensory input by providing the user with the ability to move a camera or eyepoint to observe peripheral visual data otherwise not depicted in static interaction. The use of dynamic visual interaction establishes SA at the lowest level, freeing the cognitive resources of an operator to increase higher level SA (Van Erp, Duistermaat, Jansen, Groen, & Hoedemaeker, 2006). Four dynamic visual interaction methods were identified and used in the current research to determine SA levels associated with interaction: (a) analog joystick, (b) head tracker, (c) uninterrupted hat/POV switch, and (d) incremental hat/POV switch.

The first dynamic method, analog joystick, was focused on controlling the eyepoint of the visual display using the analog X and Y axes of an USB joystick device. Implementation of this method required the capture and translation of the joystick movements (pitch/yaw) into eyepoint (camera) movement in the visual simulation. This technique was selected based on past-unmanned use and the ability to establish a comparative baseline against which the other dynamic methods could be compared.

The second dynamic method was head tracker visual interaction, a technique to manipulate a corresponding visual eyepoint using an operator's head movements to provide instinctive control, while freeing their hands for other activities (Martins & Ventura, 2009; Righetti, Cardin, Thalmann, & Vexo, 2007). Head trackers have been employed in teleoperated visual control interfaces (Amanatiadis, Gasteratos, Georgoulas, Kotoulas, & Andreadis, 2008; Righetti et al., 2007; Yamauchi & Massey, 2008) and by researchers examining SA (Martins & Ventura, 2009) or effectiveness (Brayda, Ortiz, Chellali, Mollet, & Fontaine, 2010). This technique was selected as the second alternative visual interaction method based on these past uses.

The third method was the uninterrupted hat/POV switch visual interaction method, a technique that relies on the use of an eight directional hat (POV) switch on the top of a joystick for eyepoint control. This method reflects capturing the user input from the switch and translating into a sweeping (i.e., uninterrupted) visual change in the eyepoint position. The term uninterrupted was applied to the naming of the technique to distinguish this method from the custom developed incremental hat/POV switch. This technique was selected as the third alternative visual interaction method based on existing use in simulation (FlightGear, 2011; Microsoft, 2006).

The final dynamic interaction, incremental hat/POV switch visual interaction method, was developed as a means to enable higher precision control of the eyepoint using the eight directional hat (POV) switch in contrast to the broad sweeping control provided by the uninterrupted hat/POV switch technique. This method reflects capturing the user input from the switch and translating into incremental (up, down, left, and/or right) visual change in the eyepoint position based on previous positioning and predetermined increment rate (i.e., 50 pixels per second). The design of this concept was based upon an interaction control method observed in software applications (Control Vision Corp, 2010; DynaNav Systems, 2009; Microsoft, 2006) and prior research (Sanders-Reed & Koon, 2010; Yanko, Keyes, Brury, Nielson, Few, & Bruemmer, 2007).

Experimental Research

An experimental test was performed that used each of the visual interface treatments (the levels of the independent variable), a simulated operator station, and custom developed testing software to measure the SA of a participant and the effectiveness of each treatment. The purpose of the experiment was to determine which treatment, if any, had the highest SA value for interaction with a remote egocentric visual environment. Purposive selected experimental participants were randomly assigned to a treatment type (analog joystick, head tracker, uninterrupted hat/POV switch, incremental hat/POV switch, or static eyepoint) in combination with the simulated operator station to interact with a simulation that depicted a remote location with dynamic placement of objects of interest.

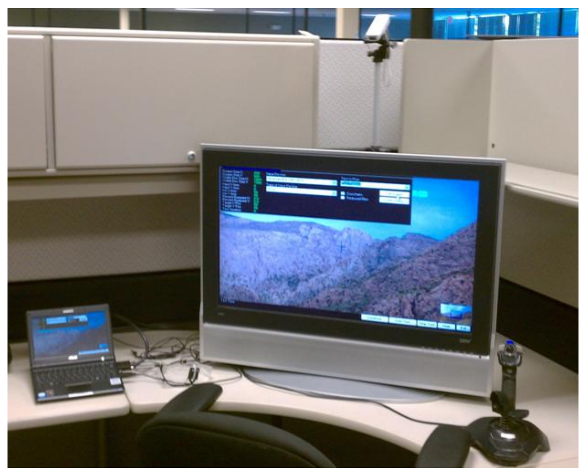

Figure 2. Simulated Operator Station and Visual Interaction Interfaces

A distinct background image and randomly located geometric objects (triangle, circle, square, red, blue, or yellow) were used in the simulation to create scenarios between a series of situational awareness global assessment technique (SAGAT) queries. The simulation was used to recreate a stationary pre-flight taxiway or runway scenario, which was controllable given the use of a dynamic eyepoint control method (analog joystick, head tracker, uninterrupted hat/POV switch, or incremental hat/POV switch). When the view was centered or if the static view was employed, only the center grid position would be visible to a participant.

The simulated scenario used in the experiment was typical in the operation of multiple types of unmanned vehicle elements in stationary positions (i.e., engine start, taxi hold point, and shutdown). The decision to use a stationary position opposed to a dynamic scene engine was made to reduce complexity associated with the simulation, while geometric objects were chosen to represent objects of interest for this study to facilitate identification of patterns for the projection (i.e., prediction) portion of SA capture and analysis.

The intent behind this research was to perform an initial examination of interaction capability using static scene location, whereas future research could investigate further using dynamic location (i.e., aircraft in flight, landing, takeoff, or target engagement). The total environment area of the simulation represented an area equal to three horizontal FOVs by three vertical FOVs (see Figure 3).

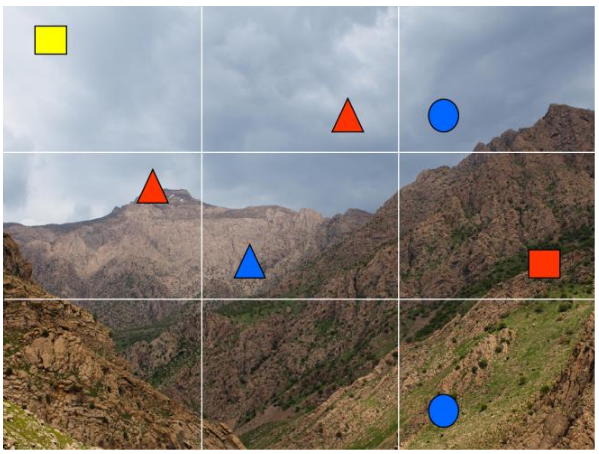

Figure 3. Depiction of Simulated Environment Subdivided by Screen FOV (3 x 3)

Test Participant Interaction

Each of the test participants (*N* = 150) interacted with a simplistic egocentric simulation and answered five randomly injected SAGAT queries (Endsley, 1988), proceeding until the test was completed. Each of the SAGAT queries consisted of three questions designed to elicit an indication of the participants SA of the environment. The result of each SAGAT query was a composite SA score (*Participant* Y_{SA}), indicating the SA level of the participant for the interaction. The composite SA scores were a 0 to 100% scale, determined by comparing the accuracy of a participant's query responses to the known state of the environment (e.g., identify number of blue objects). At the conclusion of the testing, the composite SA scores were averaged to calculate the average participant SA (*Mean Participant* Y_{SA}). All of the participant SA scores associated with the same visual interaction treatment were used to calculate an average treatment SA score (*Mean* $Y_{SA}(X)_{Treatment}$).

Procedure

The experimental test activity was initiated and observed by the test administrator once a participant indicated readiness to begin or after five minutes of pretest controls familiarization elapsed, whichever came first. At the start of the test, the participant viewed the visible environmental area (data visible on screen), which contained the randomly placed geometric objects among the five SAGAT query halts as the test progressed. If the participant was assigned a dynamic visual interaction technique, they were able to change the eyepoint, viewing the larger simulated environmental area. Otherwise, the view was locked forward in the center of the total environmental area, resulting in a reduced environmental perception.

After 99 seconds of interaction, the first of five SAGAT query halts occurred. The test administrator queried the participant with three previously determined questions to capture their composite SA score in accordance with the SAGAT process (Endsley, 1988). Once the responses to all three questions were captured, the administrator unfroze the simulation, repopulating the screen and introducing new geometric objects into the simulated environmental area. This process was repeated for the remaining four SAGAT query halt until the test administrator recorded the final responses. The final SAGAT query consisted of three projection questions used to determine the effectiveness of the treatment for prediction. The experimental test was performed once per participant (*N* = 150), lasting 15 to 30 minutes.

Data Capture and Analysis

The focus of this research was the determination of SA values associated with the use of dynamic or static eyepoint interactions (*Participant* Y_{SA}, *Mean Participant* Y_{SA}, and *Mean* $Y_{SA}(X)_{Treatment}$) within the simulated stationary egocentric environment using the SAGAT framework (i.e., randomly timed SA capture queries). The current research differed from previous research through the determination of an SA value (*Mean* $Y_{SA}(X)_{Treatment}$) associated with eyepoint interaction, the introduction of two additional dynamic interaction methods (uninterrupted hat/POV and incremental hat/POV), and the design and identification of a stationary baseline scenario for the capture of SA.

RESULTS

At the completion of experimental testing activities, the 150 individual participants scores (*Mean Participant* Y_{SA}) were recorded and used to calculate the mean SA score for each treatment (*Mean* Y_{SA} $(X)_{Treatment}$). The acquisition and maintenance of participant SA was observable in the test participant interaction with the simulation through analysis of the SAGAT scores of each participant and treatment using analysis of variance (ANOVA) and a post hoc test. The visual interaction techniques best suited to the acquisition and maintenance of SA resulted in the highest mean SA score.

The calculated mean SA score for each treatment ($Mean\ Y_{SA}(X)_{Treatment}$; Static, Analog Joystick, Head Tracker, Uninterrupted Hat/POV, and Incremental Hat/POV) and the respective stand deviations (SD) are depicted in Table 1.

Table 1. Mean Treatment SA Scores

Treatment	**Mean $Y_{SA}(X)_{Treatment}$**	**SD**
Static	54.61	8.59
Analog Joystick	94.66	4.72
Head Tracker	92.75	6.29
Uninterrupted Hat/POV	95.48	5.26
Incremental Hat/POV	92.33	6.40

The mean treatment SA scores ($Mean\ Y_{SA}\ (X)_{Treatment}$) were used in a one way ANOVA test to determine that significance difference did exist among the five mean treatment SA scores, $F(4, 145) = 226.93$, $p < .0001$.

A pair wise comparison of treatment SA scores was performed using a Scheffe test and corroborated using a Tukey test to determine the specific difference in treatment means and their statistical relevance. An $F_{Scheffe}$ variable for each treatment comparison was calculated and compared to an F statistic required for statistical significance ($F_{Req\ for\ stat\ sig}$). The performance of the post hoc testing was used to determine that the static mean SA score ($Mean\ Y_{SA}(X)_{Static}$) of 54.61 (M = 54.61%, SD = 8.59) was significantly different and lower than all four of the dynamic treatment means at an α of.05 with a probability (P) of.05 (5%). There was no significant difference among any of the dynamic treatment means.

DISCUSSION

The findings of this study indicated increased amount of visual data facilitates an increase in perception, comprehension, and ability to generate accurate projections (i.e., predictions) as observed in the analysis of the captured experimental results. Use of the dynamic eyepoint interaction methods resulted in significantly higher level of SA than use of the conventional static interaction. While the uninterrupted hat/POV switch interaction method exhibited the highest SA, with a mean treatment SA score of 95.48 (M = 95.48%, SD = 5.26), it was not statistically significant compared to the other dynamic visual interaction treatments. The findings of this study identified a clear correlation between the use of a dynamic eyepoint and an increase in SA compared to static interaction in a stationary egocentric environment.

Improved SA

Observing that all of the dynamic eyepoint SA scores were greater than the static interaction SA score indicated that dynamic eyepoint interaction represents an improvement to unmanned aircraft interaction interfaces for stationary egocentric unmanned operation (simulated scenario). Secondary observations made during the current research also indicated that use of the dynamic methods for the simulated conditions were not distracting, did not cause fatigue, and provided an increase in operator awareness, comprehension, perception, ability to project, and quantity of visual information.

The findings of this study indicated use of a static eyepoint constrained a human operator, compared to use of dynamic visual interaction for stationary egocentric environments. While the dynamic interactions resulted in a higher SA score over static, they do not all merit inclusion into actual unmanned aircraft controls systems. For example, while the analog joystick visual interaction method resulted in a mean SA score of 94.66 (M = 94.66%, SD = 4.72), an operator would have difficulty using the method while retaining control of the flight vehicle because of the potential need to use both hands exclusively with the flight controls (interface conflict).

Improved Unmanned Aircraft Operation

The lower quality of visual data from remote unmanned operations affects pilot performance when combined with reduced FOV (Menda, Hing, Ayaz, Shewokis, Izzetoglu, Onaral, & Oh, 2011). To counteract low data quality, use of dynamic visual interaction could expand operator environment data capture. Expanded data capture for systems that have the capacity for use (i.e., can support additional weight or command infrastructure) would result in a more accurate environmental model and improved SA in stationary positions.

The use of dynamic eyepoint methods increases the immersive aspect of remote environment interaction, resulting in expanded capability to perceive a remote environment. Limiting an ability of a test participant to observe the remote environment, such as employing the static visual interaction (i.e., fixed view), resulted in a reduction in ability to perceive. Conversely, use of the dynamic eyepoint methods facilitated perception of a larger portion of the remote environment and the capture of more information relating to its state.

The increased perception of visual information was used by the participant in the comprehension and development of a mental environmental model accessed from memory to answer the SAGAT queries in the experimentation. The limited view associated with the static visual interaction inhibited the test participant's ability to comprehend environment, reducing their capability to predict (project) within the simulation. Higher SA performance values of the four dynamic interaction methods over the static interaction method indicated that use of the dynamic methods for the simulated conditions provide an increase in operator awareness, comprehension, perception, ability to project, and quantity of visual information.

Unmanned aircraft operators are also limited by use of a reduced FOV, resulting in a more demanding mental process to develop a composition of an environmental model including vehicle orientation and location (Hing, Sevcik, & Oh, 2009). The increased mental workload associated with a limited FOV leads to diminished SA and disorientation, increasing the potential for mishaps or accidents (Hing et al., 2009; Menda et al., 2011). As observed in the current research, increasing the amount of visual information available through dynamic visual interaction resulted in increased SA.

One example of dynamic visual interaction implementation would be the potential redesign of Predator/Reaper camera operation. At altitudes of 500 feet or less, the orientation of the moveable Predator/Reaper camera is locked to provide an alternative redundant sensor source to the primary nose camera (Colucci, 2004). Locking the sensor camera prevents employment for dynamic visual interaction during landing, when the majority of Predator mishaps have occurred (84%; Nelson, 2009). Reducing command and control (C2) interaction by removing camera altitude locks and sensor operators from the operating process could result in reduced time to execute initial and subsequent camera orientation changes (i.e., improved response rate) and decreased susceptibility to command translation error (verbal communication).

Improved Unmanned Aircraft Interface

Creating an effective interface design requires providing an operator with the ability to comprehend the state of the unmanned aircraft (Drury & Scott, 2008). Use of the uninterrupted hat/POV switch generated a directional command to the simulated camera, expanding the visual capability compared to the static. This expanded visual capability represents an improved potential for comprehension of spatial information (i.e., remote environment information). The ability of a participant to change the view rapidly using the uninterrupted hat/POV increased the total perception area, preventing the reduction of visual information associated with using a limited FOV camera. Having an active link between a participant's thumb position and the simulated position in conjunction with a location overview display prevented perception issues associated with moveable camera views.

The two hat/POV switch based methods (incremental hat/POV switch and uninterrupted hat/POV switch) hold promise for combination into a single hybrid control to capitalize on positive characteristics, while mitigating negative. Combining these two methods could alleviate the effects of incremental hat/POV switch slow movement by implementing the quick snap-to positional movement of the uninterrupted hat/POV switch. The uninterrupted hat/POV switch limitation of not tracking objects (i.e., precise eyepoint following) could be managed using the incremental hat/POV switch functionality for precise eyepoint movement.

The hybrid functionality could be activated using a toggle feature (i.e., button press) to alternate between the two methods. Figure 4 represents a graphical depiction of the movement associated with a hybrid control using elements of the uninterrupted and the incremental hat/POV switch methods.

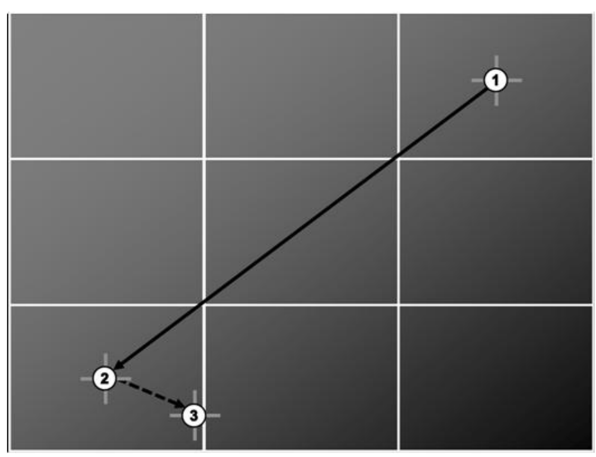

Figure 4. Hybrid Uninterrupted/Incremental Hat/POV Switch Functionality

The uninterrupted functionality could provide rapid transition from the upper right corner of the visible environment area to lower left (position one to two), while the incremental functionality could be used for fine movement (position two to three).

The practical use of a hat/POV switch in existing unmanned aircraft controls would require the addition of or remapping of a camera orientation mechanism and an associated control interface (i.e., ground control). One method worth examining is the addition of a hat/POV switch to an open location on a throttle control, accessible by the left thumb. Locating the control on the throttle assembly would ensure the pilot could maintain control of the aircraft, while also manipulating the dynamic camera view.

Automation

Another potential implication of this research is that the reduction in SA associated with use of automation, can lead to out-of-the-loop reductions in performance (Lewis & Sycara, 2011). The primary cause for out-of-the-loop performance reduction is deficient monitoring during operation (Lewis & Sycara, 2011). An example is failing to detect abnormal deviations or malfunction during the performance of automated activities (Lewis & Sycara, 2011). Providing manual dynamic eyepoint interaction during automated operation would increase the SA of the operator, while mitigating the potential for out-of-the-loop conditions pertaining to the initialization of automated aircraft movement (i.e., static hold point or automated visual interaction).

Overreliance of automated functions, such as autopilots in conventional manned aircraft operation has led to a loss in pilot skills (Granda, 2011). The FAA found that manned aircraft pilots have difficulty with manual operation or proper use of automated control in more than 60% of accidents and 30% of major incidents (Lowry, 2011). Over dependence on automation decreases a pilot's operational experience, reducing their ability to react to situations that require manual control (Granda, 2011).

Applicability to UGV

The findings of this study can also be applied to unmanned ground vehicles (UGV)s based on the similarity of the experimentation scenario (i.e., stationary ground position) and use of cameras with limited FOV. The remote environmental perception of UGVs is subject to the same constraint as unmanned aircraft, the limited FOV of the cameras (Tolic & Fierro, 2010). The ability of a UGV to operate in stationary positions to capture visual data further corresponds with the simulated scenario used in the current research. In addition, the ability of a UGV to operate in stationary positions indicates that the analog joystick method could also be used for control of the camera orientation, without the same control imitations as unmanned aircraft (i.e., overlapping use of the analog joystick control/C2 conflict).

CONCLUSION

Unmanned aircraft spending is expected to grow in the next decade from $5.9 billion per year to $11.3 billion, based on the needs of the U.S. military (Zaloga & Rockwell, 2011). A clear method to improve unmanned operation could provide significant potential for cost savings. This research indicated that unmanned operations could be improved through use of dynamic visual eyepoint interaction during static positioning (i.e., stationary aircraft holding positions).

Single operator control of an unmanned aircraft using dynamic visual interaction control increases the ability to obtain and maintain SA, while reducing the steps to change the camera orientation. Increasing the SA of an operator assists in decreasing the potential for crashes (Hing et al., 2009), which is why the U.S. Army is exploring elimination of two operator control (i.e., pilot and sensor operator) and transitioning to a system managed by a single soldier (Beidel, 2011). Use of dynamic eyepoint interaction in stationary positions could reduce the potential for mishaps and accidents by facilitating the identifying and locating objects of interest in the environment, including ground crew, support equipment, or operational hazards.

Several avenues of future research built on the findings of this study merit exploration. Such research includes examination of dynamic eyepoint interaction for active aircraft movement (dynamic environmental positioning), incorporation of dynamic visual interaction into unmanned controls, and the development of a hybrid dynamic visual control method. The benefits of performing such research are the potential to improve mission performance, expanded capability, decreased accidents and mishaps, reduced operational costs, and further understanding the relationship between dynamic eyepoint manipulation and SA.

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was performed in accordance with the Northcentral University Institutional Research Board policy.

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