THE ROLE OF SPATIAL ABILITY IN THE RELATIONSHIP BETWEEN VIDEO GAME EXPERIENCE AND ROUTE EFFECTIVENESS AMONG UNMANNED VEHICLE OPERATORS

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ABSTRACT

Effective route planning is essential to the successful operation of unmanned vehicles. Video game experience has been shown to affect route planning and execution, but why video game experience helps has not been addressed. One answer may be that spatial skills, necessary for route planning and execution, improve after experience with video games. The current study examines the degree to which spatial ability, specifically spatial visualization, mediates the relationship between video game experience and route planning. Results indicated that this mediated relationship existed for the UGV operators only. Although the UAV operators' video game experience predicted spatial ability, this did not significantly affect performance.

1. INTRODUCTION

Effective route planning is essential to the successful operation of unmanned vehicles, and especially of unmanned ground vehicles (UGVs). In many situations, the terrain is not fully known or understood, and UGV routes must be planned and executed under time pressure. This is a difficult task, and operators report high workload and low accuracy when planning and executing routes in a remotely operated vehicle. In a typical scenario, the operator is shown one or more video feeds from cameras mounted on the vehicles. Even when operating a single vehicle, and under varying levels of camera control and field of view, route planning and execution may be difficult.

1.1 Individual Differences in Route Planning

One source of difficulty is that the images on a video feed are perceptually challenging stimuli. Compared to natural vision, the video screen provides less visual information than would be available to a physically present observer. The most obvious difference is a limited field of view, known as the keyhole effect (Woods, Tittle, Feil, & Roesler, 2004). Other examples include the absence of binocular depth cues and a lack of proprioceptive information. The problem is not only a lack of information, but also the presence of conflicting perceptual cues. The operator must deal with ambiguous information that results from combining the video screen with perceptual information in the local environment. The absence of binocular depth cues conflicts with the operator's perception that the image on the screen is flat. Perception of motion by the robot must be reconciled with the operator's vestibular sense of not moving. In other words, the operator must integrate the visual information presented on screen and the conflicting perceptual cues the operator is accustomed to using.

The strategies used to reconcile the conflict between information available on the video screen and local perceptual cues vary between people. Individual differences are expected considering the relatively large number of perceptual cues available to the human vision system compared to other modalities (Cutting, 1997). It is not surprising, then, that observation of human operators planning UGV routes quickly verifies that individual differences exist in the efficiency or effectiveness of these routes.

1.2 Video Game Experience

Video games that represent a three-dimensional space present a similarly challenging perceptual task to the player. Therefore, it makes sense that experience with video games has been shown to positively affect effective route planning and execution (Rehfeld, Jentsch, Fincannon, & Curtis, 2005; Guildea 1994). Because experience with video games is related to route effectiveness, there may be utility in using video games for training. Although the use of video games for training has been examined (Rehfeld 2006), identification of the specific effects of video game experience that support transfer remains a challenge.

1.3 Spatial Ability

The remaining question, then, is why video game experience helps route planning. One answer may be that spatial skills, which are necessary for route planning and execution, improve after initial experience with video games.

Spatial ability positively predicted performance in a target identification task in a virtual three-

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dimensional maze and negatively predicted total maze movement, including backtracking (Chabris, 2006). Thus, spatial ability may provide the operator an effective strategy for dealing with the degraded perceptual environment.

Although spatial ability is sometimes considered a stable trait, a number of studies have demonstrated short-term improvements in spatial ability. In one study, spatial visualization improved with mere observational exposure to a camera rotating around a building (Rehfeld, 2006). Green examined video game experience as an individual difference through the classification of participants as video game players and non-players and found improvements in attention to objects in a spatially distributed field (2003). This same effect was demonstrated in a follow-up study where participants were exposed to 10-day video game training.

In those without any prior experience, spatial ability test scores can improve with regular play of a three-dimensional game (Dorval and Pépin 1986). Using video game training as an experimental manipulation, Gagnon (1985) found that the amount of past video game experience significantly predicted scores on spatial ability measures. For participants who began the study with little experience with video games, video game training lead to a greater spatial ability improvement than participants in a non-video game control condition. The participants in Gagnon's sample had greater spatial ability than the national average, suggesting that experience with video games can improve spatial visualization even in individuals with already high spatial ability.

1.4 Team Characteristics

Also of interest are the individual characteristics of the remote vehicle operators working in a team. While the many emergent properties of teams are outside the scope of this investigation, it is worth noting that the improvements in individual spatial ability may have different effects on the team member operating a ground vehicle than the one operating an aerial vehicle. The UAV operator, provided with a top-down view, has more information about the location of targets but without ground exposure, the operator cannot see as much detail. The UGV operator is provided with more detail but has less information about the spatial relationship between targets and location in the environment.

With respect to spatial ability, there is a growing body of research that suggests individual differences in performance. For example, Fincannon, Evans, Jentsch, and Keebler (2008a) hypothesized that, as spatial ability is associated with localization performance, it should also be related to the quality of navigation support that is provided from a UAV operator to a UGV operator. Results from their study indicated that spatial ability did interact with the amount of navigation support that was provided by UAV operators to influence UGV teammates' report of workload, as measured by the NASA TLX. Other work has also indicated that spatial ability interacts with interface design on the amount of communication that takes place between UAV/UGV operator teams (Fincannon, Evans, Jentsch, & Keebler, 2008b). Given the observed influence of spatial ability in team effectiveness, these effects are likely in other aspects of effectiveness as well.

1.5 Hypothesis

The purposes of the current research were, therefore, (a) to replicate prior findings showing a positive relationship between video game experience and the effectiveness of route planning/execution in a joint UGV/UAV simulation, (b) to study the degree to which spatial ability mediates the aforementioned relationship, and (c) to explore differences in these relationships between UGV and UAV operators. Our hypothesis was that spatial ability mediates the relationship between video game experience and effective route planning for both the UAV and UGV operators. If supported, our hypothesis will add to the understanding of the specific skills improved by video game experience.

2. METHOD

2.1 Participants

One hundred twenty students from the University of Central Florida (UCF) formed 60 two-person teams. For each team, there was one unmanned ground vehicle (UGV) operator and one unmanned aerial vehicle (UAV) operator. Each participant was randomly assigned to team roles.

2.2 Environment

Fig. 1. 1:35 scaled military operations in urban terrain (MOUT) environment

As illustrated in Figure 1, the teams completed a reconnaissance task in a 1:35 scale Military Operations in Urban Terrain (MOUT) simulation (cf. Ososky, Evans, Keebler, & Jentsch, 2007). Per the description by Ososky et al., the UAV operator was located in a

Fig. 2. Command and control (C^2) room for mounted operation of the UAV

command and control room, simulating a secure, mounted environment (Figure 2), while the UGV operator was located in a virtual foxhole (Figure 3) intended to simulate a more stressful dismounted environment. As with previous research using this facility, confederates served as 'artificial intelligence' for both the UAV and the UGV to simulate semi-autonomous operations (Rehfeld et al., 2005, Fincannon, Evans, Jentsch, & Keebler, 2008).

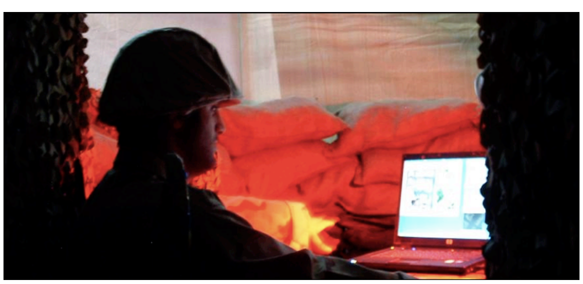

Fig. 3. Virtual foxhole of dismounted operation of the UGV

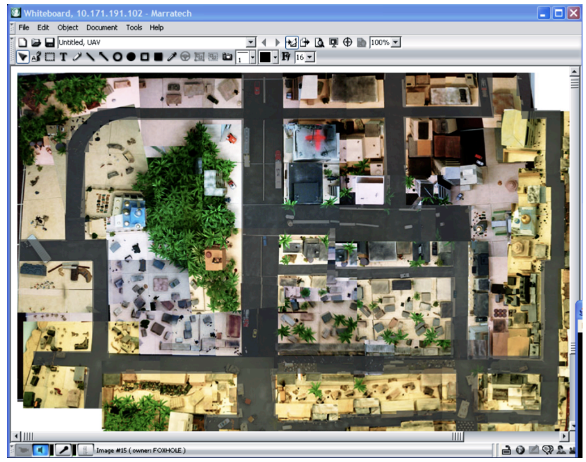

Fig. 4. Marratech software interface

Each distributed team shared access to a whiteboard and instant messaging communication via Marratech software interface. As illustrated in Figure 4, the shared whiteboard presented a map of the entire scaled facility, and participants used this interface to create mission plans. Routes for both vehicles were visible to participants during the entire course of the mission.

2.3 Measures

A biographical data form was used to assess video game experience. On this form, participants were asked to rate their "experience with seeing or working with any type of video games" by responding on a 6-point Likert-type scale from 1 (*not at all familiar*) to 6 (*very familiar*). In order to assess spatial ability, the Guilford-Zimmerman Spatial Visualization was administered.

When the researchers designed the reconnaissance missions, they were created such that only a UAV or a UGV could reach the assigned objectives. For example, the UAV in this study had a limited fly zone, and objectives that were placed outside of this area could only be reached by a UGV. In contrast, there were objectives within the fly zone and surrounded by ground obstructions, such that they could only be observed by the UAV. Through this design, three raters were able to observe the final mission maps and state the number of objectives that were reached by the correct vehicle. These ratings were found to be reliable ($ICC = .77$, $\alpha = .91$), and the average was used in the analysis.

2.4 Procedure

Upon completion of the consent form, participants completed the biographical data form, which was followed by the administration of spatial ability testing. Participants reviewed a PowerPoint presentation and completed three practice missions, a total of approximately two hours of training.

For the final performance mission, participants received a fragmented order (FRAGO) and mission maps detailing the location of mission objectives. During the course of this mission, participants planned the mission routes, and through the simulation of autonomy, vehicles followed these routes to complete the reconnaissance portion of the mission. For the purposes of this study, the ratings of the final routes were used as the measure of team effectiveness.

2.5 Analysis

Bivariate correlations were used to test the basic relationships between video game experience, spatial ability, and route planning. Hierarchical regression was used to test the final hypotheses associated with spatial ability mediating the effects of video game experience on route planning effectiveness.

3. RESULTS

Table 1
UGV Correlation Matrix ($N = 60$)

	1	2	3
1. Video Game Experience	1.0		
2. Route Effectiveness	.42***	1.0	
3. Spatial Ability	.45***	.55***	1.0
Mean	4.82	7.01	19.37
Standard Deviation	1.53	2.13	7.52

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 2
UAV Correlation Matrix ($N = 60$)

	1	2	3
1. Video Game Experience	1.0		
2. Route Effectiveness	.19	1.0	
3. Spatial Ability	.38**	.17	1.0
Mean	4.47	7.02	16.10
Standard Deviation	1.94	2.13	7.46

* $p < .05$, ** $p < .01$, *** $p < .001$

Correlations and descriptive statistics are reported in Table 1 for UGV operators and Table 2 for UAV operators. We tested for mediation through a number of steps, following the Baron and Kenny (1986) approach. Three steps are required to demonstrate the mediated relationship. First, the independent variable, video game experience, must predict the outcome variable, route effectiveness. Second, the independent variable must also predict the mediator, spatial ability. Third, the effect of the independent variable on the outcome variable must be reduced when the mediator is added.

A significant relationship was found between video game experience and route effectiveness for UGV operators, satisfying the first requirement of mediation for UGV operators. Video game knowledge also significantly predicted the proposed mediator, spatial ability for UGV operators, satisfying the second requirement for mediation.

For UAV operators, video game knowledge significantly predicted the proposed mediator, spatial ability. However, neither video game knowledge nor the spatial ability predicted route effectiveness of the team, $F(1, 58) = 2.24$, $p < .14$, $R^2 = .04$, and $F(1, 58) = 1.79$, $p < .19$, $R^2 = .03$, respectively. Because of this, we did no further analyses for UAV operators.

Table 3
Summary of Hierarchical Regression Analysis Reporting the Standardized Coefficient (ß) for the Prediction of Route Effectiveness

Variable	Step 1	Step 2
UGV Video Game Experience	.42***	.21
UGV Spatial Ability		.46***
R^2	.18***	.34***
ΔR^2		.17***

* $p < .05$, ** $p < .01$, *** $p < .001$

Results of the hierarchical regression for the UGV operators are presented in Table 3. In the second regression step, UGV operators' spatial visualization significantly predicted route effectiveness when the variance from video game experience was held constant. The addition of UGV operators' spatial visualization reduced the relationship between video game experience and route effectiveness (from $p < .001$ to $p < .08$).

4. DISCUSSION

The results replicated previous findings of a relationship between video game experience of the UGV operators and effective route planning/execution of the team. Teams having a UGV operator with more reported video game experience had more success in executing routes that reached objectives. The results further supported the hypothesis that this effect was mediated by increased spatial visualization ability.

4.1 UGV Versus UAV Operators

Interestingly, the effects of video game experience and spatial visualization ability on route effectiveness were not evident for the UAV operators. Video game experience did predict spatial visualization for the UAV operators as well; the latter, however, did not help the team improve their route choices. This was likely due to differences in route availability between the vehicles. While "no-fly zones" limited the UAV operators' possible routes, the UGVs could move much more freely. Further, UAV operators had only one dimension along which they could move their vehicle; hence fewer spatial demands characterized the UAV operators' route planning and execution tasks. Future research should study the influence of these factors on route choices and route effectiveness in unmanned vehicles. Specifically, we cannot yet separate the effect of introducing the top-down viewpoint of the UAV from the effects of limited range of movement. A future study should examine the effects of the UAV vehicle when both UAV and UGV have the same range of movement.

4.2 Limitations & Future Research

Our study did not address the amount of video game exposure needed, nor did we introduce any type of video game training. Past research suggests that even limited, passive exposure may be helpful (Rehfeld, 2006). Future research should introduce video game experience as an experimental manipulation. This will be useful to explore if the variance accounted for by exposure to video games and the degree to which they are moderated by the individuals' traits.

The specific features of video games that impact spatial visualization and the mechanisms by which this occurs are not yet known, but are relevant topics for future research. In this study, all types of video game experience were included. A future study could examine the effects of certain types of video games or features of video games, as more specificity is needed to determine if particular types of video games will have this effect. The perspectives from which a game is presented (e.g., first-person, side-scrolling), the presence or absence of three-dimensional objects in a game, and the tasks completed by the player are all interesting variables for future study.

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