# TIME TO ACCLIMATE: EXAMINING THE INFLUENCE OF COGNITIVE ABILITY ON SITUATING TO A VIDEO GAME

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**ABSTRACT**

The current study was designed to examine the relationship between cognitive ability and player experience in shaping how players think within, and acclimate to, video games as complex systems. Specifically, researchers examined the relationship between player's cognitive ability and gameplay outcomes within a video game (i.e., *The Deed*). Outcomes were evaluated and contrasted after two discrete playthroughs, each lasting approximately 30 minutes. Logistic regression indicated that cognitive ability predicted individual outcomes for both the first and second playthrough, but did not predict growth between playthroughs (i.e., outcome change). Findings are then discussed in terms of an acclimation stage.

**KEYWORDS**

Acclimation Stage, Cognitive Ability, Player Experience, Video Games

## 1. OBJECTIVES AND PURPOSE OF THE STUDY

It has long been recognized that individuals vary in their abilities to process information, construct meaning from that information, and apply it to real-world situations. Broadly speaking, that variability manifests through individual differences (e.g., cognitive ability) intersecting with contextualized experiences to produce an outcome (Goh et al, 2019; Jonassen & Grabowski, 2012). For this reason, researchers have begun to surmise that the complexity of video games, coupled with content embedded in narrative, may provide a contextualized experience through which individual differences shape learning (Schrader et al, 2019).

In line with this idea that meaning making is a complex and contextualized experience, Alexander and colleagues (2004) define expertise as a developmental process, broadly consisting of knowledge, interest, and strategic processing that grows with active engagement in a field or domain. From this perspective, previous research examining expert/novice differences within a video game have demonstrated that the situated understanding of the game itself also plays a significant role in how that contextualized experience manifests (McCreery et al, 2011). Not only do novices demonstrate difficulty with spatial navigation but also with navigating the graphical user interface (GUI) and associated information. This last point is of particular importance in that researchers and practitioners alike are unlikely to achieve their goals or outcomes if players are unable to discern how to use the system on a fundamental level. As such, McCreery and colleagues (2011) have not only suggested that an acclimation period is warranted when teaching or conducting research with video games, but also called for further research into how intra-individual differences may shape the acclimation period. Despite this call, little clarity exists with regard to how cognition shapes acclimation. For this reason, the current study set to explore the role of cognitive ability in shaping how students (players) think within, and acclimate to, a complex system (i.e. video games).

## 2. THEORETICAL FRAMEWORK

Briefly, complex systems are multifaceted (multiplicity of components), dynamic (interaction of multiple components), and emergent (evolving over time) (Hilpert & Marchand, 2018). Video games are complex systems consisting of a variety of elements (e.g., dimensional space, GUI, world objects) that afford interactions with each other and the player over time (Schrader et al, 2019). The player must possess a basic level of skill and understanding within this complex system in order to attend to and accurately interpret the feedback provided by interactions with the rules, goals, and objectives (McGonigal, 2011). These system characteristics not only interact with user characteristics (i.e., individual differences) in highly complex, dynamic, and emergent ways (Hilpert & Marchand, 2018), but they also do so in a cyclical manner, whereby game structures shape player behavior and player behavior shape game structures (McCreery et al, 2015).

Considering such complexity, researchers have sought to understand the implications individual differences have on research and instruction from, with, and within video games. For example, while examining expert-novice differences, time-series data revealed that an acclimation stage was warranted for players new to complex video game environments (McCreery et al, 2011). Defined as an orientation period that is typically represented by limited domain knowledge and problem-solving strategies (Alexander et al, 2004), the acclimation stage is of chief importance to new players. This stage allows for the opportunity to orient to the game space, navigate the GUI, and prioritize information about how feedback is presented. Without this time to acclimate, some players may miss important content intended to further game goals, which may negatively impact their ability to succeed in the game (McCreery et al, 2011).

Exploring intra-individual differences may provide context for conceptualizing the acclimation stage within video games. One such intra-individual difference that may influence acclimation is cognitive ability, as it is tied to both knowledge and strategic processing associated with a developmental perspective of expertise. Cognitive ability is characterized as both *crystallized* (when knowledge is acquired through education and experience) and *fluid* (when logic and skills are used in learning and acquiring new information) (Shipley et al, 2009).

Generally, the relationship between cognitive ability and video games can be examined through three lenses: (1) whether video games can be used as cognitive training tools to influence cognitive ability (Bediou et al, 2018; Fikkers et al, 2019), (2) whether video games can be used as a valid psychometric measure of cognitive ability (Buford and O'Leary, 2015; Quiroga et al, 2019), and (3) whether cognitive ability can influence video game performance. The first lens is interested in the use of digital games to influence or improve cognitive ability over time. Positive gains were found in the areas of attention, spatial cognition, and fluid intelligence (Bediou et al, 2018; Fikkers et al, 2019). The second lens is interested in the ability to leverage games as an environment within which to measure cognitive ability. Significant, moderate to strong correlations between in-game measures and general mental ability, fluid reasoning, and visuospatial ability shows promise that these methods are capturing the same latent cognitive factors (Buford and O'Leary, 2015; Quiroga et al, 2019). However, the current study is interested in examining the third lens, as little is known about how cognitive ability influences game play behavior and outcomes. At the time of this writing, no literature was found that explicitly used the construct of crystallized intelligence to examine its predictive relationship to video game performance. However, literature does exist that indirectly aligns with the above definition of crystallized intelligence (i.e., knowledge acquired through education and experience). For example, research examining previous video game experience and performance has demonstrated significant differences in how experienced players navigate the GUI and associated information within the game Defense of the Ancients 2 (DOTA 2) (Castaneda et al, 2016). Specifically, the more experienced the player, the less effort was spent monitoring in-game tools, and the more automated usage became. Alternatively, there is existing research that has directly examined fluid intelligence as a predictor of performance with video games (Baniqued et al, 2013; Kranz et al, 2017). For example, fluid ability was found to be positively correlated with video game performance across a variety of multiplayer online battlefield games (Kokkinakis et al, 2017). In discussions associated with this correlation, the researchers raise the possibility “that rather than games modifying cognition, learning to play video games depends on the same cognitive resources underlying performance on intelligence tests” (Kokkinakis et al, 2017, p. 7-8).

Reframing performance in video games to allow for an acclimation stage facilitates the examination of whether cognitive ability shapes how the acclimation stage emerges for players new to a particular game. Specifically, the current investigation was designed with two overarching questions as guides: a) how do individual differences in cognitive ability impact outcomes associated with a video game; and b) if players were given the opportunity to play the game more than once, would any changes in the predictive nature of cognitive ability on outcomes suggest the need for an acclimation stage? As such, the following research questions were designed:

RQ1. Does cognitive ability (Shipley-2 scores) predict gameplay outcomes for the first attempt of a new game (*The Deed*)?

RQ2. Does cognitive ability (Shipley-2 scores) predict gameplay outcomes for the second attempt of the same game?

RQ3. Does cognitive ability (Shipley-2 scores) predict the learning growth (outcome change) scores between gameplay one and two?

# 3. METHOD

## 3.1 Subjects

One hundred and forty-four (*N* = 144) participants completed the study (see Table 1). The gender breakdown included 39 males and 105 females. The racial makeup of the sample was as follows: 47% White, 7% Black or African American, 17% Hispanic or Latino, 16% Asian, 2% Native Hawaiian or Pacific Islander, 10% two or more races, and 1% other. The mean age was approximately 24 (*SD* = ~ 6) years old.

Table 1. Demographics

| *N* = 144 | | Frequency | Percent |
|---|---|---|---|
| Race | | | |
| | White | 68 | 47.2% |
| | Black or African-American | 10 | 6.9% |
| | Hispanic or Latino | 24 | 16.7% |
| | Asian | 23 | 16.0% |
| | Native Hawaiian or Pacific Islander | 3 | 2.1% |
| | Two or More Races | 15 | 10.4% |
| | Other | 1 | 0.7% |
| Gender | | | |
| | Male | 39 | 27.1% |
| | Female | 105 | 72.9% |

## 3.2 Procedures

### 3.2.1 Game Selection

*The Deed* (Grab the Games, 2015) was selected as part of a more extensive study examining forced-choice games as a model for stealth assessment. The game is considered a reverse murder mystery with problem-solving elements where the desired outcome is to gather information (i.e., evidence and weapons) to get away with a crime, rather than gathering information to solve a crime. If players are successful, they evade prison by implicating another character for their crime and may even receive the family inheritance. If they are unsuccessful, they are sentenced to prison once their crime is discovered. *The Deed* is an appropriate choice for studying the effect of cognitive ability on gameplay outcomes. Firstly, the entire game can be completed in 20-30 minutes, falling within the acclimation time period (approximately 30 minutes) outlined by McCreery and colleagues (2011). Secondly, success in the game is predicated on player ability to interact with the content and narrative.

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### 3.2.2 Data Collection

Data were collected during the 2017-2018 academic year from subject pool participants within a college of education in the southwestern United States. Participants were asked to complete a demographic questionnaire, followed by a first playthrough of *The Deed* (Grab the Games, 2015) video game. Participants were not provided verbal gameplay directions; rather the game provided a built-in introduction prior to gameplay. Following the first playthrough, participants completed the Shipley-2, and then completed a second playthrough of *The Deed*. All gameplay was captured for later coding and analysis using Fraps (Version 3.5.99) (Beepa Pty Ltd., 2013). The summative outcome was determined by reviewing the game capture footage.

## 3.3 Instruments

### 3.3.1 Deed Outcome Data

Outcome data were calculated by creating a dichotomous score based on video observations of the players' activity. Specifically, overall outcome scores were coded as failure (prison and no inheritance = 0) or success (no prison with or without inheritance = 1). Further, learning growth scores were coded as nongrowth (do the same or worse from Playthrough One to Playthrough Two = 0) or growth (do better on Playthrough Two compared to Playthrough One = 1).

### 3.3.2 Shipley-2

The Shipley-2 (Shipley, et al., 2009) is a brief measure of crystallized (e.g., prior knowledge) and fluid intelligence (e.g., problem-solving). Subtest scores are provided for Vocabulary (crystallized intelligence), Abstraction (fluid intelligence), and Block Patterns (fluid intelligence). Composite scores are labeled as: Composite A (Vocabulary with Abstraction) and Composite B (Vocabulary with Block Patterns). Composites A and B also each provide an Impairment Index score (not used in this study). Reviews for the Shipley indicate solid reliability and validity data to support its use (Hayes & Thorndike, 2010).

## 4. RESULTS

Prior to analyses, the Box-Tidwell (1962) test was conducted to check that the assumption of linearity was upheld. For all analyses, interaction terms were found to be nonsignificant, $p_{min} = .092$. We then proceeded to the main analyses of interest. The Shipley-2 subscales were used as continuous predictor variables (see Table 2). Gameplay Outcome was coded as a dichotomous nominal variable, with "0" denoting a failed outcome and "1" denoting a successful outcome. Gameplay Growth was also coded as a dichotomous nominal variable, with "0" denoting nongrowth and "1" denoting growth between the first and second playthrough outcomes. Although logistic regression allows for the classification of outcomes, that was not the purpose of this study.

Table 2. Descriptives

| *N* = 144 | Mean | SD |
|---|---|---|
| Shipley-2 Subscales | | |
| Vocabulary | 104.431 | 11.021 |
| Abstraction | 107.194 | 15.008 |
| Block Patterns | 107.556 | 14.599 |

## 4.1 RQ1

Analyses containing cognitive ability should maintain the structure of the composite scales (Sattler, 2008). Therefore, two separate binary logistic regression analyses were conducted to address the first research question: a) Vocabulary and Abstraction (Composite A) as the predictors of Playthrough One Outcome; and b) Vocabulary and Block Patterns (Composite B) as the predictors of Playthrough One Outcome (see Table 3).

### 4.1.1 RQ1a

The logistic regression model with Vocabulary and Abstraction as predictors was statistically significant, $\chi^2(2) = 13.864$, $p = .001$. The model explained 13.3% (Nagelkerke $R^2$) of the variance in outcome and showed good fit, Hosmer-Lemeshow: $\chi^2(8) = 6.948$, $p = .542$. Vocabulary was a significant predictor of gameplay outcome ($B = .062$, SE = .021, $e^B = 1.064$, Wald $\chi^2(1) = 8.787$, $p = .003$) whereas Abstraction was nonsignificant (Wald $\chi^2(1) = .784$, $p = .376$). As participants' vocabulary scores increase, there is as an associated increase in the likelihood of attaining a successful outcome on Playthrough One.

### 4.1.2 RQ1b

The logistic regression model with Vocabulary and Block Patterns as predictors was also statistically significant, $\chi^2(2) = 16.269$, $p < .001$. The model explained 15.5% (Nagelkerke $R^2$) of the variance in outcome and showed good fit, Hosmer-Lemeshow: $\chi^2(8) = 10.793$, $p = .214$. Vocabulary was again a significant predictor of gameplay outcome ($B = .063$, SE = .020, $e^B = 1.065$, Wald $\chi^2(1) = 9.581$, $p = .002$) while Block Patterns was nonsignificant (Wald $\chi^2(1) = 3.069$, $p = .080$). As participants' vocabulary scores increase, there is as an associated increase in the likelihood of attaining a successful outcome on Playthrough One.

Table 3. Logistic regression of cognitive ability predicting outcomes on playthrough one

| Variable | B | SE B | $e^B$ | Wald $\chi^2$ (1) | *p* | % Success (1) |
|---|---|---|---|---|---|---|
| Vocabulary | .062 | .021 | 1.064 | 8.787 | .003 | |
| Abstraction | .013 | .014 | 1.013 | .784 | .376 | |
| Nagelkerke $R^2$ | .133 | | | | | |
| $\chi^2(2)$ | 13.864 | | | | .001 | 27.1 |
| Vocabulary | .063 | .020 | 1.065 | 9.581 | .002 | |
| Block Patterns | .025 | .014 | 1.026 | 3.069 | .080 | |
| Nagelkerke $R^2$ | .155 | | | | | |
| $\chi^2(2)$ | 16.269 | | | | .000 | 27.1 |

Note: $e^B$ = Odds Ratio

## 4.2 RQ2

Following the same structure as above, two separate binary logistic regression analyses were conducted to address the second research question: a) Vocabulary and Abstraction (Composite A) as the predictors of Playthrough Two Outcome; and then b) Vocabulary and Block Patterns (Composite B) as the predictors of Playthrough Two Outcome (see Table 4).

### 4.2.1 RQ2a

The logistic regression model with Vocabulary and Abstraction as predictors was statistically significant, $\chi^2(2) = 6.365$, $p = .041$. The model explained 5.8% (Nagelkerke $R^2$) of the variance in outcome and showed fair fit, Hosmer-Lemeshow: $\chi^2(8) = 13.684$, $p = .090$. However, while the overall model was significant, neither of the individual predictors was significant (Vocabulary: Wald $\chi^2(1) = 2.666$, $p = .103$; Abstraction: Wald $\chi^2(1) = 1.898$, $p = .168$).

### 4.2.2 RQ2b

The logistic regression model with Vocabulary and Block Patterns as predictors was also statistically significant, $\chi^2(2) = 12.278$, $p = .002$. The model explained 10.9% (Nagelkerke $R^2$) of the variance in outcome and showed good fit, Hosmer-Lemeshow: $\chi^2(8) = 5.334$, $p = .721$. Block Patterns was a significant predictor of gameplay outcome ($B = .034$, SE = .012, $e^B = 1.034$, Wald $\chi^2(1) = 7.439$, $p = .006$) while Vocabulary was again nonsignificant (Wald $\chi^2(1) = 3.384$, $p = .066$). As participants' Block Patterns scores increase, there is as an associated increase in the likelihood of attaining a successful outcome on Playthrough Two.

Table 4. Logistic regression analysis of cognitive ability predicting outcomes on playthrough two

| Variable | B | SE B | $e^B$ | Wald $\chi^2$ (1) | *p* |
|---|---|---|---|---|---|
| Vocabulary | .027 | .016 | 1.027 | 2.666 | .103 |
| Abstraction | .017 | .012 | 1.017 | 1.898 | .168 |
| Nagelkerke $R^2$ | .058 | | | | |
| $\chi^2(2)$ | 6.365 | | | | .041 |
| Vocabulary | .030 | .016 | 1.030 | 3.384 | .066 |
| Block Patterns | .034 | .012 | 1.034 | 7.439 | .006 |
| Nagelkerke $R^2$ | .109 | | | | |
| $\chi^2(2)$ | 12.278 | | | | .002 |

Note: $e^B$ = Odds Ratio

## 4.3 RQ3

To address research question three, a learning growth score was created wherein the outcome score from Playthrough One was subtracted from the outcome score from Playthrough Two. All nonpositive values were coded as a “0” for nongrowth and all positive values were coded as a “1” for growth. Binary logistic regression models were then analyzed (Vocabulary and Abstraction as predictors of Growth; Vocabulary and Block Patterns as predictors of Growth). Results indicated that neither regression model was significant ($\chi^2(2) = 1.334$, $p = .513$; $\chi^2(2) = 3.116$, $p = .211$, respectively; see Table 5).

Table 5. Logistic regression analysis of cognitive ability predicting outcome growth

| Variable | B | SE B | $e^B$ | Wald $\chi^2$ (1) | *p* |
|---|---|---|---|---|---|
| Vocabulary | .008 | .016 | 1.008 | .228 | .633 |
| Abstraction | .011 | .012 | 1.011 | .758 | .384 |
| Nagelkerke $R^2$ | .012 | | | | |
| $\chi^2(2)$ | 1.334 | | | | .513 |
| Vocabulary | .009 | .016 | 1.009 | .341 | .559 |
| Block Patterns | .019 | .012 | 1.019 | 2.489 | .115 |
| Nagelkerke $R^2$ | .029 | | | | |
| $\chi^2(2)$ | 3.116 | | | | .211 |

Note: $e^B$ = Odds Ratio

# 5. DISCUSSION

Previous research has shown the importance of both individual differences (Goh et al, 2019; Jonassen & Grabowski, 2012) and an acclimation stage (Irizarry & Kleyn, 2011; McCreery et al, 2011) for successful interactions with complex environments. In an effort to expand our understanding, the current study set out to examine the relationship between cognitive ability and player experience on gameplay outcomes. Based on the results of research question one, Vocabulary (i.e., prior knowledge) was predictive of success for the first playthrough. As players’ vocabulary scores increased, the likelihood of attaining success in the game on the first playthrough also increased. Results of research question two indicated that Block Patterns (i.e., problem-solving) was predictive of success for playthrough two. As players’ block pattern scores increased, the likelihood of attaining success in the game on the second playthrough also increased. Results of research question three indicated cognitive ability was not predictive of growth between playthroughs.

These findings illustrate several important points. Players rely on prior knowledge and experience (crystallized intelligence) when initially navigating a complex video game environment. During the acclimation stage (i.e., first playthrough), players develop situated knowledge and experience contextualized by the video game content and narrative. However, over time, the reliance on extant knowledge diminishes. Once players acclimate to the system, they are able to better rely on problem-solving (fluid intelligence) to more deeply engage in the experience, rather than having to integrate prior knowledge with a new experience. These results align with previous findings that indicate the presence of, and need for, an acclimation stage (Irizarry & Kleyn, 2011; McCreery et al, 2011; Schrader et al, 2011).

Findings suggest that the situated understanding of context and narrative is critical when designing a research study that examines game-based outcomes. Situations and storylines often provide clues and distractors that can influence outcomes (McCreery et al, 2019). For researchers, this means it would be prudent to understand how those situations and storylines may shape study findings prior to conducting game-based research. For example, if the purpose of the study is to examine content knowledge, but situations and storylines are vague, then it is quite possible the study is testing problem-solving rather than content knowledge. Research design also should account for an acclimation stage in which respondents gain a situated understanding of the game. In the context of the current study, the lack of situated understanding in the first playthrough demonstrated the importance of intra-individual differences in players' prior knowledge and experience. We recommend that study design be considerate of sampling procedures, particularly where novice gamers or new gaming environments are concerned, as this lack of experience could be a confound in outcome studies. Therefore, it may be helpful to use a gamer experience measure to more closely normalize sample experience levels or perhaps provide a tutorial to participants when introducing them to a novel game space. In both cases, this may strengthen the researchers' ability to control for how prior knowledge impacts outcomes.

In the second playthrough, the presence of situated understanding was demonstrated by the statistically significant increase in success rates, from 39 to 73 successes, from the first to second playthrough ($t(143) = 4.375$, $p < .001$). In order to assess the impact of problem-solving, participants should possess a situated understanding of content and narrative to draw from and apply to the contextualized experience. The inclusion of an acclimation time period is integral to providing participants a chance to develop an understanding of the system. This last point is of particular importance to researchers, in that rather than examining study outcomes, the lack of an acclimation time period may shift the focus toward unintentionally studying participants developing a familiarity with the system, and therefore increasing Type II errors.

Finally, the lack of significance associated with the third research question was expected based on the findings of research questions one and two. Specifically, each experience with the game highlighted separate cognitive abilities needed to acclimate and progress within the video game. As crystallized and fluid intelligence are related yet distinct ($r = .38$) (Shipley et al, 2009), they play substantially different roles. The reliance on crystallized intelligence in playthrough one highlights the reliance on prior knowledge and experience; while findings associated with fluid intelligence in playthrough two suggest that the player is becoming situated and engaging in more problem-solving activities. Taken together, this suggests that rather than contributing to growth, they appear to be demonstrating that acclimation is a process. The current study does come with limitations. Specifically, it sits within a sparse body of literature. As such, these findings need to be both replicated and expanded across different game contexts and genres. Cognitive ability was also examined in isolation of other constructs of interest. Future research may look to include these constructs within extant theoretical frameworks in order to interpret their significance within a more comprehensive model.

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