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Can we create a measure of fluid intelligence using Puzzle Creator within Portal 2?

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ABSTRACT

Researchers have suggested that video games can be used to measure cognitive abilities (e.g., Boot, 2015). To that end, we wanted to test the feasibility of developing a measure of fluid intelligence within a commercially-available video game. We created a 15 chamber (i.e., problems to be solved) test called the "Portal 2 Test Battery" using the Puzzle Creator within the popular problem-solving video game Portal 2. In study 1, 35 video game players (VGPs) who had experience playing Portal 2 completed this test and Ravens Advanced Progressive Matrices (RAPM), a validated measure of fluid intelligence, revealing a strong relationship ($r = .65$) between the two. In study 2, 100 participants, both VGPs and non-video game players (nVGPs) completed the Portal 2 Test Battery, RAPM, and the Bochumer Matrices Test (BOMAT), another validated measure of fluid intelligence. Structure equation modeling revealed a strong relationship between the latent variables fluid intelligence and portal ability ($r = .78$). Additionally, the reliability of our test was acceptable in both studies ($\alpha = .80$ and $\alpha = .76$). These results provide the first evidence that it may be feasible to create a measure of fluid intelligence using the Puzzle Creator within Portal 2.

1. Introduction

"Video games are increasingly being used by psychologists to aid in our understanding of skill acquisition, cognitive capacity and plasticity, development and aging, and individual differences (p. 1; Boot, 2015). Indeed, over the past 30 years, video games have been used as valuable research tools to provide insight into skill acquisition (e.g., Mané & Donchin, 1989), spatial cognition (e.g.Gagnon, 1985, Ventura, Shute, Wright, & Zhao, 2013), intelligence (e.g.Quiroga et al., 2009, Rabbitt, Banerji, & Szymanski, 1989), and attention (e.g.Bejjanki et al., 2014, Green & Bavelier, 2003).

Space Fortress, a complex game developed by cognitive psychologists as part of the Defense Advanced Research Projects Agency's Learning Strategies Program, is a perfect example of how a game can be used to better understand cognition, and more generally, as a research tool. This game allowed researchers to better understand skill acquisition in a complex and controlled environment, requiring high levels of perceptual, cognitive, and motor skills (Donchin, 1995; Mané & Donchin, 1989), and has continued to provide a wealth of information on skill acquisition for more than twenty years (e.g., Lee et al., 2012).

More recently, Quiroga et al. (2009) showed that general intelligence is related to some video games, but not others. Specifically, they examined three different games from Big Brain Academy (Wii) and found that they correlated differently with general intelligence (g). The *Calculus* game was not related to g; the *Memory* game was moderately related to g; and the *Train* game was strongly related to g. Additionally, the strength of the relationship between the *Train* game and g increased as participants continued to play the game over time, resulting in a very strong relationship at the end of the study ($r = .67$). Thus, research suggests that different video games make use of different cognitive abilities including intelligence.

Ventura et al. (2013) capitalized on the heavy spatial and navigational components that underlie many video games to measure spatial ability. Specifically, they created the virtual spatial navigation assessment (VSNA), a custom browser-based game. They found significant relationships between the VSNA and three measures of spatial ability (viz., the mental rotation test, the spatial orientation test, and the Santa Barbara sense of direction scale). Importantly, in response to a growing number of studies that suggested the need to assess spatial ability in our education system (e.g., Wai, Lubinski, & Benbow, 2009; Uttal et al., 2013), they noted that the VSNA "could potentially be used for large scale assessment since it is scalable and quick to administer" (p. 6), thus showing how the VSNA could have application beyond laboratory research.

Combining the previous research that shows that certain video games are related to intelligence (Quiroga et al., 2009; Quiroga et al., 2015), that video games can be created to measure different aspects of cognition (e.g., Ventura et al., 2013), and Boot's (2015) suggestion that "custom games can be used as a way to measure cognitive abilities" (p. 2), we sought to develop a measure of fluid intelligence within a

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commercially available video game. Fluid intelligence is the ability to solve novel scenarios, independent of previously acquired knowledge (e.g., Carpenter, Just, & Shell, 1990). We chose this as the construct of interest because 1) many commercially-available video games exist that fall into the puzzle-platform or problem-solving genre and 2) many researchers have called for a better understanding of individual differences in intelligence within various environments (e.g., Hunt & Jaeggi, 2013).

Measuring fluid intelligence inside of a video game offers researchers more than just a new method of assessment. First, a test placed inside of a commercially-available video game could capitalize on the billions of individuals who play video games (Diele, 2013). That is, it could be taken from home with limited or no instruction within a platform that they already own. If individuals are already familiar with the game they are playing, they would only need to load the test and complete it to the best of their ability. This could be an ideal scenario for a pre-screen that may inform a psychologist or clinician. Second, researchers can capitalize on "stealth assessment" (p. 2) as individuals would be comfortable playing the game, reducing levels of test anxiety or nervousness; this could lead to less biased scores (Boot, 2015). Third, when individuals are playing a game they enjoy, they become more engaged and immersed in that game, which can lead to a state of flow or *being in the zone*. This state is ideal for test taking because individuals are completely focused and motivated to complete the task at hand (Csikszentmihalyi, 1990; Csikszentmihalyi & Csikzentmihaly, 1991) and are not bored by the dull nature of our traditional standardized tests (Boot, 2015).

1.1. Portal 2

Portal 2, an award winning game by the Valve Corporation, is one such problem-solving game that requires players to solve a series of puzzles or obstacles to complete each chamber (i.e., problems to be solved) in the game (Valve Corporation, 2011). This game is ideal for our purposes because 1) the game is based around solving novel problems, 2) the game has many unique mechanics that allow for the construction of many chambers using many different combinations of rules, and 3) Valve Corporation developed the *Puzzle Creator*, an editor that allows anyone to create new chambers (i.e., problems to be solved), a feature that would allow anyone to create as many chambers as desirable with a range of difficulties.

More specifically, Portal 2 is a first-person perspective problem-solving video game (Valve Corporation, 2011). The player is placed inside of a chamber and the objective is to exit (i.e., escape) to "complete" the chamber. Each chamber has a number of obstacles that players must find solutions for in order to successfully exit. For example, players can open two portals and then travel between them. This would be useful in a scenario where an object is blocking a path or if no path exists between two separate areas within the chamber (see Figs. 1 and 2). Other more simple game elements include the ability to activate buttons, ramps, and bridges to facilitate travel within the chamber (see Table 1). Thus, the game has many sets of rules that can be created and shifted to solve problems. See the Supplementary Materials for more information about Portal 2, including videos and guides for chambers from the test battery.

2. Study design

In study 1, we recruited video game players (VGPs) with prior experience playing Portal 2. They completed the Portal 2 Test Battery (see the Method section) and the Raven's Advanced Progressive Matrices (RAPM) test, a validated measure of fluid intelligence (Raven, 1990; Raven & Court, 1998; Raven, Court, Raven, & Kratzmeier, 1994). In study 2, we expanded our sample to include both VGPs and non-video game players (nVGPs). All participants completed the Portal 2 Test Battery, the RAPM test, and the Bochumer Matrices Test (BOMAT), another validated test of fluid intelligence (Hossiep, Turck, & Hasella, 1999). Our goal was to determine whether we could find a strong relationship between completion scores on the Portal 2 Test Battery, RAPM, and the BOMAT for both VGPs and nVGPs, suggesting that it may be feasible to create measures of fluid intelligence using Puzzle Creator within Portal 2, independent of video game experience.

2.1. Study 1

2.1.1. Method

2.1.1.1. Participants. Thirty five students (9 female, $M = 21.3$ years, $SD = 2.6$) from George Mason University participated for course credit. All participants reported playing video games regularly and all had experience playing Portal or Portal 2.

2.1.1.2. Tasks and materials

2.1.1.2.1. Portal 2 Puzzle Creator. The Portal 2 Puzzle Creator is an editor that is available to anyone who owns the game. This editor allows players to create chambers for others to solve. Players have access to all of the normal items and objects available in Portal 2, can create as many chambers as they want, with as many or as few objects, items, and rules as they want (see Supplementary Materials).

2.1.1.2.2. Test construction. We used the Puzzle Creator to develop dozens of chambers (i.e., problems to be solved by participants). After pilot testing, we created a battery of 15 chambers for assessment (videos of many of the chambers are available online with guides on how to solve them, see Supplementary Materials). Pilot testing including brining in undergraduate and graduate students ($n = 20$) to attempt to complete and comment on the chambers. We wanted to know if they could complete the chambers, how long it took them, how hard they subjectively thought each chamber was, whether they had the game knowledge to complete the chamber (i.e., understanding the basic mechanics through practice), and any other feedback that they could provide. The following were the guidelines we used to create the chambers and the test battery.

1. We designed each chamber to *not* require a high level of hand–eye coordination to be successfully completed. Instead, we wanted the problem-solving process to drive the solution. We had concerns that experienced video game players would have an advantage that could inflate their scores if we required high levels of hand–eye coordination to complete the chambers. An example of a task within Portal 2 that would require a high level of hand–eye coordination is retargeting a portal in the middle of a momentum jump to move to a new area. This must be done quickly and has little room for error. Importantly, actions such as these do not rely on problem-solving ability.
2. For each chamber in the test battery, we either introduced a new rule (i.e., game mechanic) that had not been previously shown within the test battery or we used a combination of previously shown rules. In total, 11 chambers introduced new rules and 4 chambers used a combination of rules previously encountered. These rules range from common game mechanics such as traveling between portals to advanced mechanics such as using momentum jumps to move objects. See Table 2 for a list of rule(s) used.
3. Similar to other fluid intelligence tests, we attempted to make the test progressively more difficult. Pilot data was used to estimate the difficult of each chamber.

2.1.1.2.3. Portal 2 Test Battery. Our test battery consisted of 15 separate chambers that participants completed one at a time. The objective in every chamber was to successfully exit the chamber. To do this, participants would need to solve the puzzle within that specific chamber. Participants were given up to 5 min to solve each chamber. Pilot data suggested that 5 min was enough time to solve each problem. For each chamber, once you have figured out the solution, it takes less than 30 s to execute it and exit the chamber. The test ascended in difficulty based on data from pilot testing.