Exploring the Relation between the Theory of Multiple Intelligences and Games For the Purpose of Player-Centred Game Design

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Abstract: A large body of research work demonstrates the importance and effectiveness of adapting a learning game to its players. This process is driven by understanding the differences between individuals in terms of abilities and preferences. One of the rather interesting but least explored approaches for understanding individual differences among learners is Gardner's theory of Multiple Intelligences (MI). Gardner suggests that people exhibit multiple dimensions of intelligence or abilities. In the literature, it is suggested that people with different types of intellectual strengths (intelligences) often exhibit clear preferences toward specific modalities and types of interaction and content in relation to learning. This raises the question whether this knowledge could be transferred and employed in adapting learning games to players, more in particular for the purpose of improving the game and/or learning experience, as well as the learning outcome of the players. Although various claims regarding the existence of a relationship between MI and games have been made, none of them are substantiated with empirical evidence.

This paper presents the results of an empirical study that has led to evidence-based mappings between the different dimensions of intelligences proposed in MI and the fundamental building blocks of games, i.e. game mechanics. These mappings indicate which game mechanics suit which MI dimensions, and can therefore act as design guidelines when designing games targeting people exhibiting dominance for specific MI dimensions. A tool that visualizes these mappings and facilitates their use in the design of such player-centred (learning) games is also presented.

Keywords: Multiple intelligences; Game preferences; Game mechanics; Evidence-based; Game design; Learning games

1. Introduction

Adapting learning games to their players has proven to be an effective way for improving the game experience and learning outcome of the players (e.g. Grappiolo et al. 2011; Kickmeier-Rust & Albert 2010; van Oostendorp et al. 2013; Muir & Conati 2012; Parnandi & Ahmed 2014). Many different aspects of players have already been considered as the driving force in such an adaptation process: e.g. knowledge level, attention, engagement, task skill, and learning style. The so-called intelligences of the players based on the theory of Multiple Intelligences (MI) (Gardner 2011) however, have been largely neglected. Gardner has stated that human intelligence is multi-dimensional. He defined eight distinct dimensions of intelligences, where each dimension focuses on specific abilities to solve problems or to create products. Furthermore, he stressed that everyone possesses every intelligence dimension but to different degrees. Chan (2005) suggested that people with different intelligences or intellectual strengths often exhibit clear preferences toward specific modalities and types of interaction in relation to learning and self-expression. This raises the question whether these MI dimensions could be useful to the process of adapting a game to (some of) the characteristics of players, and if so how could this be done. In particular, we are interested in **using the MI dimensions in *player-centred game design* for the purpose of improving the game and learning experience of the players**. The term player-centred game design is used to refer to the design process of a game targeting a group of players with specific characteristics.

Possible relationships between the theory of MI and game constructs, as well as its potential for adaptation of games have been discussed by different scholars (McCue, 2005; Becker, 2007; Jing et al, 2012; Chuang & Sheng-Hsiung, 2012; Starks, 2014; Lepe-salazar, 2015). Although this seems to be a promising direction to follow, empirical evidence for the existence of such relationships is virtually non-existent. Such evidence is not only crucial for determining whether this theory can be potentially used in the adaptation of (learning) games, but also for supporting game designers and developers in making informed decision about the game constructs to incorporate in their design when taking players' intelligences into consideration.

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This paper reports on a research aimed at establishing empirical grounds for incorporating the theory of MI in player-centred game design. As such, we first investigated the existence of aforementioned relationships by means of a survey study, measuring the participants' intelligences and their preferences for specific games. Secondly, to understand the underlying causes for the observed correlations, we analysed the considered games based on their fundamental building blocks (i.e. game mechanics). Based on this analysis, mappings between the different MI dimensions and game mechanics were established. The rest of this paper is structured as follows: we first briefly explain the theory of MI (section 2) and explore related work (section 3). We then explain the survey (section 4) and next the derivation of the mappings between MI dimensions and game mechanics (section 5). Furthermore, we discuss the implications of our findings (section 6), and lastly we elaborate on limitations and future direction of this research (section 7).

2. The theory of multiple intelligences (MI)

The theory of MI draws a framework for defining individual differences between people in terms of their abilities and preferences. According to Gardner (2011), an intelligence is "*the ability to solve problems, or to create products, that are valued within one or more cultural settings*" (ibid. page xxviii). Eight distinct intelligences or so-called MI dimensions were proposed. Each dimension represents a different way of thinking, problem solving and learning. They are defined as follows (The Components of MI, 2016):

- Visual-spatial intelligence represents the ability to conceptualize and manipulate large-scale spatial arrays (like a pilot does), or more local forms of spaces (like an architect).
- Bodily-kinaesthetic intelligence is the ability to use one's whole body, or parts of the body, to solve problems or create products (like a dancer).
- Musical-rhythmic intelligence implies having sensitivity to rhythm, pitch, meter, tone, melody and timbre (like a musical conductor). This may entail the ability to sing, play musical instruments, and/or compose music.
- Linguistic intelligence suggests sensitivity to the meaning, order, sound, rhythms, inflections, and meter of words (like a poet).
- Logical-mathematical intelligence is the capacity to conceptualize the logical relations among actions or symbols (like a mathematician).
- Interpersonal intelligence represents the ability to interact effectively with others and being sensitive to others' moods, feelings, temperaments and motivations (like a negotiator).
- Intrapersonal intelligence implies being sensitive to one's own feelings, goals, and anxieties, and the capacity to plan and act in the light of one's own traits. Intrapersonal intelligence is not particular to specific careers; rather, it is a goal for every individual in a complex modern society, where one has to make consequential decisions for oneself.
- Naturalistic intelligence is the ability to make consequential distinctions in the world of nature as, for example, between one plant and another, or one cloud formation and another (like a taxonomist).

Note that everyone possesses every MI dimension but to different degrees (Gardner, 2011). All dimensions work together in an orchestrated way and they can influence each other. For instance, Castejon et al (2010) analysed and compared the different theoretical models of the structure of those intelligences using Confirmatory Factor Analysis (CFA) and showed that the different dimensions of MI are not independent.

We recognize that controversies exist concerning the theory of MI. Opponents have argued that there is a lack of strong empirical evidence to support the claim that eight distinct intelligence dimensions exist (see Brody, 2006; Waterhouse, 2006a; 2006b). Proponents have argued that "*a theory is not necessarily valuable because it is supported by the results of empirical test, rather its value depends on the contribution it makes to understanding and to practice in the field*" (Chen, 2004, page 22). Furthermore, studies using instruments developed to measure the values for the different dimensions show that people indeed differ in terms of their so-called intelligences (e.g. Akbari & Hosseini 2008; Castejon et al. 2010; Marefat 2007; Naeini & Pandian 2010). Therefore, we believe that it is worthwhile to investigate whether MI dimensions can be useful for adaptation of learning games.

3. Related work

The related work considering the theory of MI and games can be divided into two groups. The first group is about the potential relationship between the theory of MI and games. The most prominent works in this group

are the ones of Becker (2007) and Starks (2014); they have suggested that relationships between MI dimensions and certain characteristics of games exist. We briefly explain these suggestions.
Becker (2007) argues that there is a link between the written and spoken elements and instructions in games and the development of the linguistic intelligence. According to Becker, "*this is one reason why children often experience success in learning to read through games like Pokémon*" (Page 371). Similarly, she maps musical intelligence to a game's soundtrack and auditory feedback, referring to games such as Karaoke Revolution; logical-mathematical intelligence to in-game strategizing, arithmetic, management style and puzzle games such as Pikmin; visual-spatial intelligence to the graphical environment, visual elements of games and how they are perceived through the screen; bodily-kinaesthetic intelligence to games that promote physical movement as well as the different physical states a player experiences while playing a game such as Dance Dance Revolution; intrapersonal intelligence to games that involve ethical dilemmas and moral decision making such as Black & White; interpersonal intelligence to multiplayer collaboration, communication and competition; and naturalistic intelligence to realistic portrayal of natural environments in games such as Zoo Tycoon.

Starks (2014) provides similar arguments, stating that in-game graphics engage a person's visual intelligence, while the way a player moves in the game environment engages their spatial intelligence. She also states that social relationships inside and surrounding a game refers to the use of the interpersonal intelligence, like in MMO games; that empathy provoking situations inside a game, such as in Darfur is Dying, engage a person's intrapersonal intelligence; that music and sounds engage a player's musical intelligence; that narrative and language used inside the game engage the linguistic intelligence; that components like arithmetic, calculations and geometry, as well as pattern detection and logical deduction activate logical-mathematical intelligence; that in-game actions requiring actual physical movement engage bodily-kinaesthetic intelligence; and that realistic representations and simulations of natural environments engage a player's naturalistic intelligence. It is important to note that the observations of Becker (2007) and Starks (2014) are solely based on their theoretical analyses, and they do not provide empirical evidence for their claims.

The second group of studies focus on investigating the development of players' intelligences through games. Unlike the first group, they provide some empirical evidence for their claims. In (Crescenzi-Lanna & Grané-Oró, 2016) the importance of developing the MI of children at an early age is stressed. The study analyses 100 educational apps (including games) for children under the age of eight. The results indicate that the majority of the apps focus on the visual-spatial and logical-mathematical dimensions. The results also show that other dimensions such as kinaesthetic, interpersonal, intrapersonal or musical are neglected, even though they are developmentally essential for children at that age. Jing et al (2012), provide an overview of several educational games that can aid in the development of a player's logical-mathematical intelligence. Similarly, Chuang and Sheng-Hsiung (2012) claim that games can be used as a tool to enhance players' intelligences and learning outcomes. Li et al (2013) have investigated the effect of Role Playing Games on intrapersonal intelligence.

To the best of our knowledge, there is no academic work that provides a mapping between the theory of MI and game mechanics. However, research work that relates other types of personal differences with game mechanics could offer an interesting frame of reference. In this context, we can mention the work of Jason VandenBerghe, called "Engines of Play". VandenBerghe (2012, 2013) focused on personality traits rather than intelligences, and defined a mapping between the Big Five (Goldberg 1990) and game mechanics. The purpose of this mapping is to know which game mechanics to incorporate in the design of games to boost the players' motivation. In the domain of learning games, the Learning mechanic-Game mechanic model (Arnab et al. 2014; Lim et al. 2015) links game mechanics to different pedagogical and learning theories. The links were extracted from serious games following different pedagogical or learning theories.

4. Empirically-validated relationships between MI dimensions and preferences for games

To investigate whether MI dimensions can be used for adapting learning games to players, we started by performing a comprehensive survey study to investigate the existence of relationships between MI dimensions and preferences for games. This survey study is described in section 4.1. In search for an explanation for the results, we investigated whether the type or genre of the games could explain the results. This is described in section 4.2.

4.1 Survey

This section elaborates on the methodology used for the survey study (sections 4.1.1, 4.1.2 and 4.1.3), and reports on its findings (section 4.1.4)

4.1.1 Data collection

An online survey (http://goo.gl/5v6wOR), comprised of three sections was created and launched on July 17th of 2015. After 8 days, 308 participants had completed the survey and the response rate started to drop. We were confident that this number of participants would suffice for drawing conclusive statements, and therefore we proceeded with the collected data.

The first section of the survey contained seven questions that inquired about the demographic information of the participants (gender, age range, and level of education), as well as their game-related background information (frequency of gaming, experience with different game platforms or devices, preferred game genres, and hands-on experience with game design or development). This information would enable us to determine the heterogeneity of the sample, as well as investigating the effect of personal and contextual factors such as age, education and prior experiences.

The second section of the survey was designed to assess the strength of the MI dimensions of the participants. This was performed using the Multiple Intelligences Profiling Questionnaire (MIPQ) (Tirri & Nokelainen, 2008; Tirri & Nokelainen, 2011). The participants were asked to rate 31 statements on a scale of 1 to 5 to measure the eight MI dimensions. Each dimension was measured using four questions, except for the naturalist intelligence dimension that was measured by three questions.

Table 1: 47 game titles selected for the study. ([S] represents game series)

Intelligence dimension	*Selected games*
Visual-spatial	World of Warcraft, Minecraft, Dirt[S], Portal[S], Angry Birds, Tetris
Bodily-kinaesthetic	Xbox Fitness, Street Fighter[S], Boom Blox, Kinect Sports, Wii Sports Resort, Just Dance[S], Dance Central Spotlight[S], Dance Dance Revolution[S], Fantasia: Music Evolved
Musical	Guitar Hero[S], Audiosurf, Rock Band, SingStar[S], Bit. Trip Runner, Just Dance[S] , Dance Central Spotlight[S], Dance Dance Revolution[S], Fantasia: Music Evolved
Linguistics	The Typing of The Dead[S], Wordament, Scribblenauts[S], Wordfeud, Ace Attorney[S]
Logical-mathematical	The Room[S], 2048, Braid, Where's My Water?, L.A Noir, Heavy Rain
Interpersonal	The Sims[S], DayZ, Life is Strange, Second Life, Farmville[S], Word of Warcraft, The Walking Dead, Heavy Rain
Intrapersonal	Fable[S], Black & White[S], Infamous[S], Mass Effect[S], Fallout[S], Heavy Rain, The Walking Dead
Naturalist	Endless Ocean, Spore, Plan It Green, Flower, Afrika

The third section of the survey contained a list of 47 game titles (see Table 1) that the participants were asked to rate (1 to 5 stars) to reflect their *enjoyment of and preference towards the game* (i.e. 1 star represents lowest and 5 stars highest enjoyment of and preferences towards a game). The participants were explicitly instructed to only rate the games that they had previously played. The list of games was compiled such that for each MI dimension five game titles were provided (i.e. 40 titles in total). The list of games was compiled in collaboration with a team of avid gamers and academic game experts, and based on the suggestions found in the literature on the mapping between games and MI dimensions (Becker 2007; Starks 2014). Seven games that could be related to more than one MI dimension were also added because of their unique design and popularity. We decided to limit the size of the list to reduce the time required to complete the survey in order to maximize participation.

4.1.2 Sampling and population

As we targeted an international population of frequent gamers, we spread calls for participation through social media targeting online communities of avid gamers, game designers, developers and researchers (Facebook, LinkedIn, Google+, Reddit, and Twitter). We also reached out by email to academic communities focusing on game research (DIGRA, IGDA, DIGRA Australia, IFIP and CHI-WEB). In the aforementioned period, 465 people responded, of which 308 participants (97 females and 211 males) completed the survey. An overview of the age range distribution is presented in Figure 1.

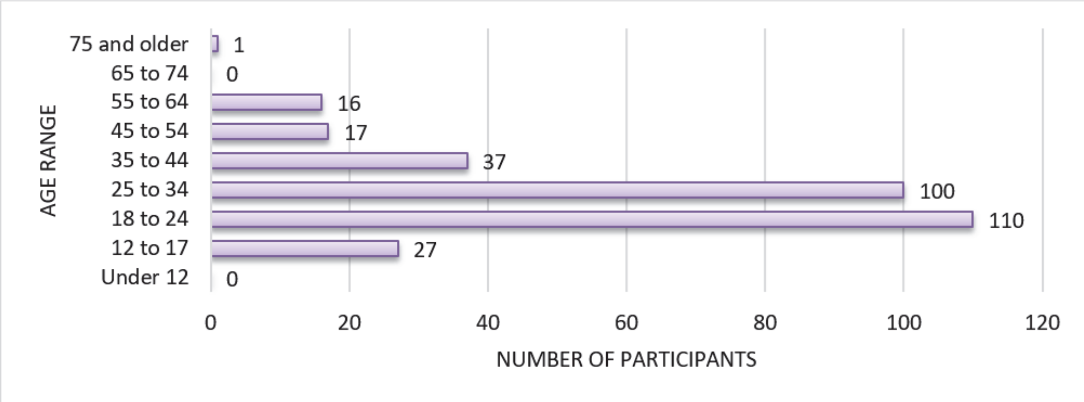

Figure 1: Distribution of participants' age range

Based on the self-reported frequency of gaming activity, 82.79% of our sample can be considered avid gamers (playing every day or 3-6 times a week). Based on the results of MIPQ, the distributions of the participants' dominant MI dimensions were obtained (see Figure 2). This distribution shows that in our sample, there were more players with dominant logical-mathematical and intrapersonal intelligence, while the rest of the MI dimensions were somewhat heterogeneously distributed, allowing us to draw conclusions about all MI dimensions. A MI dimension was considered "dominant" if the sum of the scores on the individual questions for the dimension was above 15 (out of 20) or 12 (out of 15) in the case of naturalistic intelligence.

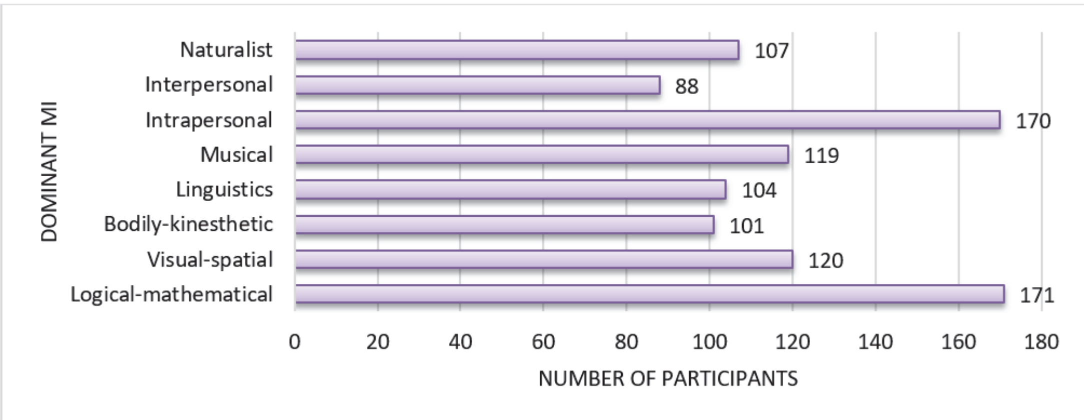

Figure 2: Distribution of Participants' dominant MI

4.1.3 Data analysis

Instead of directly hypothesizing that specific correlations exist between MI dimensions and preferences for certain games, we first opted to unveil any existing patterns in our dataset. If patterns would emerge, then we could hypothesize that correlations exist within our dataset. We therefore first analysed the data by means of factor analysis (FA). Using the extraction method "Principal Component Analysis" and the "Promax" rotation method, the FA provided us with sufficient evidence that patterns do exist in our data. We then opted to test for every possible significant correlation between MI dimensions and game preferences by means of bivariate correlation analyses using the Spearman's rho on two levels. On the first level, the correlations between the participants' MI levels and preferences for all game titles were tested. This aided us in identifying significant correlations, as well as the direction of the correlations. On the second level, in order to understand the cause and nature of the correlations, correlations between preferences for game genres and MI dimensions were tested.

4.1.4 Results

FA between each MI dimension and the 47 games was repeated 8 times to identify patterns (once for each MI dimension). Not all game titles were found to be part of these patterns, however those that do (20 in total) can be grouped into factors, here called *Intelligence-game factors*, shown in Table 2. More precisely, each column in this table represents the results of the pattern matrix of a single FA, indicating the factor representing the pattern between the game titles and the targeted MI dimension. The coefficients in Table 2 represent regression weights that capture the relationship (i.e. strength and direction) between respectively a MI dimension or a game title and an intelligence-game factor. The results of FA provided us with adequate incentive to hypothesize that *"correlations exist between participants' MI dimensions and their game preferences"*.

Table 2: Summary of the 8 pattern matrices of FA tests. KMO for linguistics .767, logical-mathematical .765, visual-spatial .766, bodily-kinesthetic .763, musical .766, interpersonal .765, intrapersonal .767, naturalistic .765; Sig. levels for KMO and Bartlett's tests .000 ([S] represents a game series)

MI dimension	***Factors***							
	intelligence-game factor ***1*** ***(linguistics)***	*intelligence-game factor* ***2*** ***(logical-mathematical)***	*intelligence-game factor* ***3*** ***(visual-spatial)***	*intelligence-game factor* ***4*** ***(bodily-kinaesthetic)***	*intelligence-game factor* ***5*** ***(musical)***	*intelligence-game factor* ***6*** ***(interpersonal)***	*intelligence-game factor* ***7*** ***(intrapersonal)***	*intelligence-game factor* ***8*** ***(naturalistic)***
Linguistics	.409							
Logical-Mathematical		.881						
Visual-Spatial			.317					
Bodily-Kinaesthetic				.917				
Musical					.821			
Interpersonal						-.738		
Intrapersonal							.334	
Naturalistic								-.536
Games								
Boom blox						.357		.432
Wii sports resort								.561
Dirt[S]			.338					
Angry Birds			.544					
Tetris					-.460			
Street Fighter[S]	.344				-.329			
Just Dance[S]							.461	
Dance Central Spotlight[S]							.395	
Dance Dance Revolution[S]	.469						.622	
Guitar Hero[S]	.530						.569	
Rock Band	.599						.643	
Wordfeud			.402					
SingStar[S]			.432		.339			
2048		.308	.574					
Where's My Water?			.345					
Heavy Rain	.543		-.315				.432	
The Sims[S]		-.398		-.371				
Endless Ocean		-.302				.487		.450
Spore			.358					
Flower	.531						.408	

Next, bivariate correlation analyses between game preferences and MI dimensions' levels (or strength), showed significant correlations for each of the eight MI dimensions and several game preferences. Note that for this analysis, each MI dimension was represented by a single value (see section 4.1.2).

Table 3: Summary of the bivariate correlation analyses. + (positive), - (negative), P < 0.01 ** or P < 0.05* (S represents game series)

Game Genre	**Game Title**	***Linguistics***	***Logical-Mathematical***	***Visual-Spatial***	***Bodily-Kinaesthetic***	***Musical***	***Interpersonal***	***Intrapersonal***	***Naturalist***
Puzzle	Portal[S]	+ *	+ **					+ **	
	Angry Birds	+ *			+ **		+ *		
	The Room[S]	+ *		+ **					
	2048	- *	+ **	+ *				- *	
	Tetris				+ **		+ *		
	Where's My Water?				+ **	+ **	+ *		
	Scribblenauts							+ *	
Word puzzle	Wordfeud								- *
	Wordament		- *					- *	
Puzzle/action	Braid	+ **	+ **				+ *		+ *
Action	Street Fighter	+ *				- *			+ *
Action/sandbox	Minecraft			+ *	+ *				
Action/adventure	L.A. Noire	+ *		+ *		+ *		+ *	
	Heavy Rain	+ **	- *					+ **	
	Infamous[S]				- *				
Action/shooter	DayZ			+ *	+ *		+ *		
Action/RPG/shooter	Mass Effect[S]				- *			+ *	
Music/dance/rhythm/action/platformer	Bit.Trip Runner					+ *			
Action/educational	The Typing of the Dead				- *	+ **			
Music/dance	Rock Band	+ *				+ *		+ **	+ *
	SingStar[S]	+ *		+ *		+ *	+ **		
	Just Dance[S]	+ *		+ *	+ **		+ **	+ **	+ **
	Fantasia: Music Evolved		+ *	+ *		+ *			
	Dance Central Spotlight[S]			+ *	+ *				+ *
	Dance Dance Revolution[S]				+ *	+ *	+ *		
	Guitar Hero[S]					+ **			
	Audiosurf							+ **	
Simulation	The Sims[S]	+ *	- **	+ **					
	Afrika		+ *	+ **					
Simulation/adventure	Endless Ocean	- *	- *		- *		- *		
	Spore			+ **		+ *		+ *	
Simulation/RPG	Second Life			+ **				+ **	
	Farmville[S]						+ **	+ **	
Adventure	Flower	+ *						+ **	
	Ace Attorney[S]			- **	- *				
	The Walking Dead	+ **						+ **	
RPG	Fable	+ *	+ **	+ *				+ *	
	Fallout[S]	+ **	+ **	+ *			+ *		
	World of Warcraft		- *	+ *				+ **	
Sports	Xbox Fitness		+ *					+ *	
Racing	Dirt[S]			+ **		+ *			- **
Strategy	Black & White[S]	+ **		+ **			+ *		

To gain a deeper understanding of these correlations, the bivariate correlation analysis was repeated focusing on the individual questions of the MIPQ, rather than on the single value for each MI dimension. The results highlighted which questions were correlated to specific game preferences. Note that it is possible for a game preference to show correlation with an MI dimension presented by a single value, as well as with the questions for that dimension. However, these two correlations could be of different degrees. To ease the application of our results, we have combined the results of both levels into a single table that shows positive ('+') or negative

('-') correlations and their significance levels (indicated by * for P < 0.05 and ** for P < 0.01). The results of this multi-level approach are summarized in Table 3. Cautious readers will note that the results of this test (i.e. the specific correlations) sometimes deviate from the results of the FA. This slight discrepancy is caused by the difference in assessment techniques used by both analytic methods. Nonetheless, we have attained empirical evidence for the existence of a relationship between MI dimensions and games.

The results of our study provide empirical evidence that partly confirms the theoretical suggestions made by Becker (2007) and Starks (2014). Although we have managed to provide empirical evidence for the existence of significant correlations between MI dimensions and games, our results are in some cases not neatly in line with the theoretical mappings suggested by Becker and Starks. For instance, Becker states that there is a link between logical-mathematical intelligence and in-game strategizing, arithmetic, management style and puzzle games. However, the logically-mathematically intelligent people in our population also exhibit a significant preference for games that require extensive physical movement such as *Fantasia*: Music Evolved and Xbox Fitness (see Table 3). This is a rather interesting finding, which raises the question: *What makes certain games be preferred by players who exhibit dominance for a certain MI dimension?* Our first hunch was that this could be the genre of the games.

4.2 Follow-up analysis and results

To investigate whether the obtained correlations could indeed be explained in terms of preferences for particular game genres, the genres of the game titles that showed correlations were extracted using the official website of Pan European Game Information (PEGI) at http://www.pegi.info/en/index/ (see Table 3), commonly used in the gaming industry. The results suggest that the correlation between MI dimensions and game preferences cannot be explained independently in terms of unique preferences for one or multiple game genres. To confirm our claim, we performed a bivariate correlation analysis using the participants' *explicit preferences* for game genres obtained from the first section of the survey (see Table 4).

Table 4: Bivariate correlation analysis between MI and explicit game genre preferences. + (positive), - (negative), the values represent the strength of the correlation at P < 0.01 ** or P < 0.05*

Game genre	***Linguistics***	***Logical-Mathematical***	***Visual-Spatial***	***Bodily-Kinaesthetic***	***Musical***	***Interpersonal***	***Intrapersonal***	***Naturalistic***
Action/adventure		-.095*			+.115*			
Adventure								+.112*
MMO								
Platform/platformer					+.145**			
Puzzle				+.146**				
RPG		-.119*						
Racer								
Rhythm/dance					+.198**		+.126*	
Shoot 'em up							-.135**	
Sims		-.118*		-.100*	-.105*			
Sports		+.114*						
Strategy		+.141**				+.150**		

The result of this analysis shows that, for instance, the "action/adventure" genre is correlated with the logical-mathematical and musical dimensions, whereas MI dimensions such as visual-spatial are not correlated with any genre. Moreover, certain genres seem to correlate with the majority of MI dimensions. These overlaps and internal conflicts indicate that no unique combinations of game genres could independently explain the relationships between MI dimensions and game preferences. An explanation could be that the categorization into game genres is only based on one aspect of the game and that preference is probably based on different aspects (Sajjadi, Vlieghe, et al. 2016b). Therefore, to identify the underlying cause for the obtained correlations, we decided to investigate whether we would be able to establish mappings between MI dimensions and the games' fundamental building blocks (i.e. game mechanics).

5. Evidence-based mappings between MI dimensions and game mechanics

In order to draw relationships between MI dimensions and game mechanics, the games that correlated to the different MI dimensions were analyzed based on their mechanics. Many scholars have defined the term game mechanic (e.g. Sicart 2008; Lundgren & Bjork 2003; Rouse III 2010). Sicart provided one of the most comprehensive definitions: “*methods invoked by agents, designed for interaction with the game state*” (ibid 2008) (Paragraph 25).

To identify which game mechanics were utilized by each of the games, a comprehensive repository of game mechanics was needed. Numerous existing repositories of game mechanics were found (e.g. Arnab et al., 2014; “Game Mechanic Mixer; Gamification Wiki; SCVNGR’s Secret Game Mechanics Playdeck; Social game mechanics; Hamari & Järvinen, 2011; Järvinen, 2008; Lim et al., 2015; Louchart & Lim, 2011; Oberdörfer & Latoschik, 2013). Many of these repositories are quite elaborate and show significant overlaps. Despite the overlaps, the different repositories do show discrepancies in terms of the number of mechanics and their labels and definitions. Thus, for the purpose of this research, we have compiled a comprehensive list of game mechanics based on existing repositories and complemented it with game mechanics that we have identified ourselves during the analysis of the games used in our study. This process led to the creation of a repository of 236 distinct game mechanics, which can be found online[1].

Furthermore, we decided to also consider the role a game mechanic plays inside a game. For this, we used the categorization of Fabricatore (2007), i.e. core and satellite mechanics. Core mechanics are “*the set of activities that the player will undertake more frequently during the game experience, and which are indispensable to win the game*” (Page 12), and the satellite mechanics are “*special kinds of mechanics, aimed at enhancing already existing activities*” (Page 13) (ibid 2007). Next, the games that were either negatively or positively correlated to one or more MI dimensions were analysed to discover which game mechanics they were using and in which role.

5.1 Methodology

For each MI dimension, two clusters were created: a *positive* cluster containing the games having a positive correlation with the dimension, and a *negative* cluster containing the games having a negative correlation with that dimension. Subsequently, each of the games were analysed with respect to the 236 game mechanics to determine whether the mechanic was used as either core (c) or satellite (s), or not used. An example of such analysis with respect to four mechanics and some of the games that were correlated to the logical-mathematical dimension is given in Table 5. The positive cluster is indicated in grey. This process was repeated 8 times, once for each MI dimension.

Table 5: Example analysis of game mechanics for the Logical-mathematical intelligence dimension (fragment)

Mechanics	***Portal***	***2048***	***Braid***	***Fable***	***Fallout***	***Xbox Fitness***	***Wordament***	***Heavy Rain***	***The Sims***	***World Of Warcraft***
Discovery	*c*		*s*	*c*	*c*			*c*		*c*
Epic meaning			*s*	*s*		*c*		*c*	*s*	
Infinite gameplay		*c*				*s*	*c*		*c*	*s*
Motion				*s*		*c*				

We established the following rule to determine whether a mechanic is related to an MI dimension: the mechanic should be utilized by at least half of the games correlated to that dimension in either the negative or the positive cluster. This rule considers the fact that if more than half of the games correlated to a MI dimension in each cluster are not using a particular game mechanic, there is not sufficient evidence that this

[1] Available at: https://goo.gl/hGYRdM

game mechanic plays an important role in the preference (or lack thereof) for these games. However, if the majority of the games in either of the two clusters utilize the game mechanic, then it is reasonable to conclude that the game mechanic has an influence on the game preference (or lack thereof) of the players. For example, the results for the game mechanics from Table 5 can be seen in Table 6. The "Discovery" game mechanic for the logical-mathematical dimension is used in 4 out of 6 games in the positive cluster, and in 2 out of 4 games in the negative cluster. This means that at least half of the games in each cluster utilize the game mechanic "Discovery", and therefore the mechanic is related to the dimension. For example, the mechanic "Motion" (i.e. the players' bodily stances (postures, gestures, etc.) produce input to the game system or benefit in dealing with its challenges) turns out not to be related to the logical-mathematical dimension: only 2 out of 6 game utilize this mechanic in the positive cluster, and no game utilizes it in the negative cluster.

Table 6: Example of the decision protocol for a relationship between the "discovery" mechanic and the logical-mathematical dimension of MI

Mechanics	***Portal***	***2048***	***Braid***	***Fable***	***Fallout***	***Xbox Fitness***	***Total weight***	***Wordament***	***Heavy Rain***	***The Sims***	***World Of Warcraft***	***Total weight***
Discovery	*c* (+2)		*s* (+1)	*c* (+2)	*c* (+2)		***7***		*c* (+2)		*c* (+2)	***4***
Epic meaning			*s* (+1)	*s* (+1)		*c* (+2)	***4***		*c* (+2)	*s* (+1)		***3***
Infinite gameplay		*c* (+2)				*s* (+1)	***3***	*c* (+2)		*c* (+2)	*s* (+1)	***5***
Motion				*s* (+1)		*c* (+2)	***3***					***0***

If there is a relationship between a game mechanic and an MI dimension according to the previous rule, we distinguish between three types of relationships: "positive", "dubious" (uncertain), and "negative" (see Table 7). To decide on the nature of the relationship we assigned a weight to the game mechanic for the positive and for the negative cluster and compared these two weights (see Table 6). The weight is calculated as follows: each time the game mechanic is used as a core mechanic in the cluster +2 is added and when it is used as a satellite mechanic +1 is added.

If the total weight in the positive cluster is larger than the one for the negative cluster by at least 2, that game mechanic is declared to have a "positive" relation with that dimension. If the total weight for the negative cluster is larger than the one for the positive cluster by at least 2, the game mechanic is declared to have a "negative" relation with that dimension. In the other case (i.e. equal weights or the difference is at most one) the relationship is called "dubious", meaning that we do not have evidence that is mechanic is either strongly positively or strongly negatively related to that dimension.

Table 7: Results of the decision from Table 6

Mechanics	***Decision***
Discovery	***Positive***
Epic meaning	***Dubious***
Infinite gameplay	***Negative***

For example, the "Discovery" game mechanic is related to the logical-mathematical dimension. This game mechanic plays three times the role of "core" and once the role of "satellite" in the positive cluster, giving it a total weight of 7 in this cluster; it plays two times the role of "core" in the negative cluster, giving it a total weight of 4 in this cluster. Therefore, this game mechanic is declared to have a positive relation with the logical-mathematical dimension. Using this protocol, the game mechanic "Infinite gameplay" has a negative relation with logical-mathematical dimension, and the game mechanic "Epic meaning" has a dubious relation with this dimension. The decisions for the mechanics given in Table 6 are given in Table 7.

5.2 Results

Our analysis showed that within our sample, the 8 MI dimensions have relationships with 116 different game mechanics. These mappings can be used to help game designers to select game mechanics when creating games for a specific audience (i.e. player-centred game design). A positive relationship indicates that players with the particular intelligence will generally respond positively to the game mechanic. As a consequence, we can *recommend* the use of this game mechanic to enhance the game experience of players with this particular intelligence. Game mechanics with a negative relationship to a particular MI dimension evoke mostly negative responses and therefore it is *recommended not to use them* when targeting players with this particular intelligence. Dubious relationships point towards a fairly equal mix of positive and negative responses. Therefore, game mechanics with a dubious relationship can be used for players with this particular intelligence but require extra caution. As an example, the "quick feedback" mechanic has a positive relationship with most of the MI dimensions, indicating that it can be recommended for all dimensions. On the other hand, the "infinite gameplay" mechanic has a negative relationship with logical-mathematical, linguistics and intrapersonal dimensions, indicating that it is recommended not to incorporate this mechanic in games designed for players with high levels for those intelligences. The "helping" mechanic has a dubious relationship with two dimensions. This means that its incorporation in games designed for those dimensions is neither encouraged nor discouraged. If more than one dimension is targeted, the choice for using a dubious mechanic can be based on the type of relationship that this mechanic has with the other dimension(s). For example, the game mechanic "reaction time" has a positive relationship with the logical-mathematical, and a dubious relationship with the bodily-kinaesthetic dimension. If a game is to be designed targeting both these dimensions, this mechanic could be used (Sajjadi, Vlieghe, et al. 2016a).

5.3 Recommendation tool

The mappings between 8 MI dimensions and 116 game mechanics is a large amount of data. In order to facilitate its use for game designers and researchers, we developed a kind of recommender tool. The tool visualizes the mappings between MI dimensions and game mechanics. The user can filter on one or more MI dimensions. The "concept network" visualization technique is used for this and implemented using D3js (https://github.com/d3/d3). This visualization is shown in Figure 3. A MI dimension is represented by a node in the centre, where the different game mechanics are the surrounding nodes and are linked to the dimension when there is a relationship. The user can hover over the MI dimensions to highlight (in blue) the relationship.
In order to see the type of relationship between a dimension and the correlated game mechanics, the user can click on a dimension node. This generates a different visualization that provides the definition of that dimension and the type of the relationships (positive, negative or dubious) using 3 different colours (green for positive, yellow for dubious, and red for negative) (see Figure 4). The user also has the ability to click on a game mechanic node. This generates a visualization that provides the definition of that mechanic and the relationships it has with the different MI dimensions.

Since the number of possible relations between each MI dimension and game mechanics can be very large, a classification of game mechanics (10 classes) (Figure 5) has been introduced, which can be used as a filtering mechanism. Each class is represented by a different colour. For example, an orange dot is used for mechanics of the class "motivation" (see Figure 4). This feature makes it easier to recognize game mechanics of a particular type. In addition, if a game designer is looking for mechanics related to motivation, he can use the filter to only receive mechanics of this class.

Lastly, a game designer can select the game mechanics he wants to include in his design. From this selection, a report can be generated providing an overview of the nature of the relationships with the selected dimensions. An example report is given in Figure 6. This report helps the game designer to detect possible conflicts that could arise as a result of targeting more than one MI dimension. For example in Figure 6 we see mechanics that have a positive relation with one of the selected dimensions, but a negative one with the other selected dimension. Note that it is up to the designer to decide whether to replace the mechanics by more suitable ones, or to keep them when there are good reasons for this, e.g. because they are essential for the game or goal under consideration.

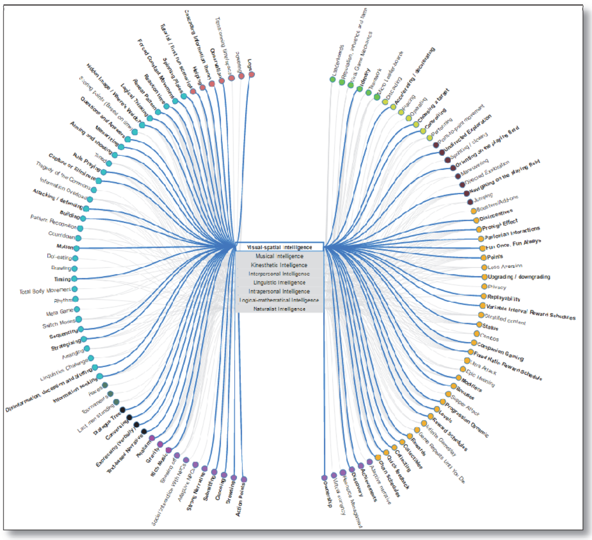

Figure 3: Main visualization: Visualization of all MI dimensions and game mechanics

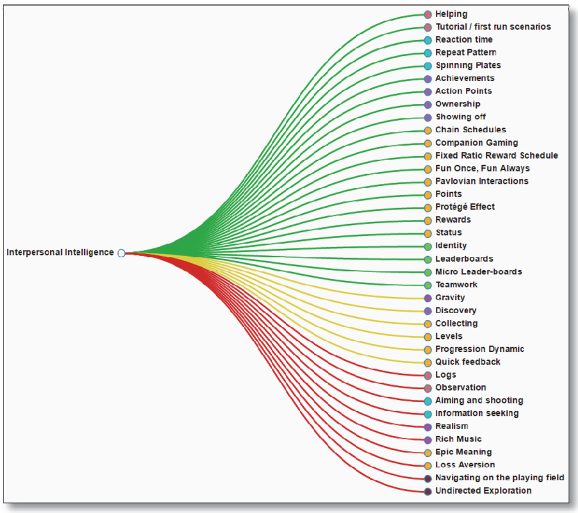

Figure 4: Dimension visualization: Visualization of the nature of the relations between an MI dimension and game mechanics

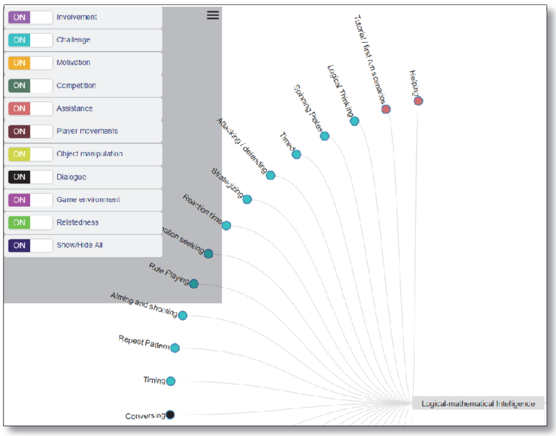

Figure 5: Game class filtering panel and unfiltered mechanics of Logical-mathematical dimension of MI

Mechanic(s)	Logical-mathematical Intelligence	Kinesthetic Intelligence
Tutorial / first run scenarios	positive	dubious
Aiming and shooting	positive	negative
Logical Thinking	positive	
Bonuses	positive	positive
Levels	positive	negative
Quick feedback	positive	dubious
Spinning Plates	dubious	dubious
Action Points	dubious	
Fixed Ratio Reward Schedule	dubious	dubious

Figure 6: Report generation for multiple dimensions of MI

6. Discussion and conclusions

In this paper we addressed the question whether the theory of MI could be useful for the process of player-centred game design, and if so how to do this. We tackled this question by first investigating the existence of empirical relationships between the different dimensions of MI and preferences for games. This investigation was performed my means of a survey study. Using factor analysis (FA) on the data obtained from the survey, we managed to find patterns between MI dimensions and game preferences. This result provided us with enough incentive to hypothesize the existence of correlations and test for their significance levels. Based on the results of bivariate correlation analyses, we established empirical evidence for the existence of correlations. Furthermore, our results indicated that the theoretical mappings suggested in the literature (Becker 2007; Starks 2014) could be refined.

To understand how the theory of MI could be used in the process of player-centred game design, recognizing the cause of the observed correlations was imperative. Therefore, we started by considering the genres of the games as possible cause. A comparison between the analysis of the implicit and explicit preferences for game genres revealed that the genres of games on their own are too limiting to explain the common characteristics shared among the game titles that correlate to certain MI dimensions. Therefore, we decided to investigate the fundamental building blocks of games, also known as game mechanics, as a possible explanation for the correlations. Following a protocol, relationships between game mechanics and the different MI dimensions were drawn. These relationships, i.e. mappings, can be positive, negative or dubious. These mappings can be of great value for player-centred game design, as they indicate what game mechanics are appropriate or not when designing games that target players with specific dominant MI dimensions.

Based on the results presented in this paper, we can conclude (1) that gamers' MI dimensions and their game preferences have multiple strong relationships; (2) that the relationships between MI dimensions and game preferences cannot be explained only by game genres; and (3) evidence-based mappings between game mechanics and the different MI dimensions exist, which can facilitate the use of the MI theory for player-centred game design. Note that these mappings could also be used in other contexts than player-centred game design, e.g. to dynamically adapt learning games to the player or to stimulate the development of certain intelligences.

7. Limitations and future work

Although our study was designed with the utmost care, inevitably, there are some limitations. Firstly, we recognize that our selection of game titles represents a snapshot of the current landscape of popular video games, and that any selection unavoidably influences the outcome of the study. However, to minimize any effect, we carefully selected a broad range of games. Naturally the list should be updated for future studies. Furthermore, although the focus and intended application of our findings is in the context of games for learning, a compilation of commercially available entertainment games have been used in the survey. This could be seen as a limitation, but the use of learning games instead of popular commercial games would have certainly reduced participation, as these games are not as widely known and played. For future research it would be interesting to perform a similar survey (probably with a smaller sample size) to investigate whether the findings obtained from the commercial games also apply for learning games.

Secondly, we acknowledge the risk of bias associated with self-evaluation. We are convinced, however, that this was the best approach given the subject of our study, the sample size and the resources. Additionally, the instrument used for measuring the MI dimension levels of the participants was an already existing and validated instrument that has also been used in other research works.

Thirdly, we admit the subjectivity associated with the analysis concerning the game mechanics used in a game and their role, and the proposed protocol for establishing the mappings. In future work, the sensitivity of the results due to this subjectivity should be investigated, e.g. by asking different people to perform the same analysis and by trying out different protocols for establishing the mapping.

The results presented in this paper enable game designers to take the dominant MI dimensions of their players into account when designing (learning) games. Whether doing so would create the desired effect, i.e. positively influencing the game experience and learning outcome of the intended audiences, is a question that needs to be addressed in future research. Already two experiments were conducted in this context and showed positive results (Sajjadi, El Sayed, et al. 2016; Sajjadi, Lo-A-Njoe, et al. 2016).

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