Command Systems And Player-Avatar Interaction In Successful Fighting Games In Light Of Neuroscientific Theories And Models

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ABSTRACT
Videogames allow the player to control an avatar with a virtual body that shares biological features with his or her own physical body. In neuroscience models of cognition in which perception, execution and imagination of movements are tightly related has recently emerged. As such, I approach the study of human-fighting game interaction by using neuroscience theories and models. Fighting games are based on martial arts and thus seem the perfect case study for this purpose. In a comparison between Street Fighter, Tekken, Mortal Kombat and Soulcalibur command systems, different features will be analyzed alongside some of the neuroscientific findings that may be useful in understanding not only how players' cognitive processes differ in these games, but also design flaws that interfere with the players experience.

Author Keywords
Fighting games; command system; spatial compatibility; perspective-taking; embodied cognition.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
When controlling an avatar in a virtual space, a player acts on a device that translates his or her movements into avatar's actions. Many modern games abandon the classic button/stick (or button/mouse) configuration to move to the realm of gestures or full body tracking (Wii, Kinect, virtual reality as a whole come to mind as obvious examples), thus directly mapping player's movements into avatar' movements, but the vast majority of the gaming experience is still mediated by platforms that use devices such as gamepad/joystick/keyboard and mouse. Here, the player who acts on the input device is limited to finger, hands and, at most, arms. The visual representation of the avatar's action that results from the inputs of the player is only seldom related with the actual movement that the player performed, though. Indeed, an avatar's kick, punch, shot, shift, jump, run, interacting or most other actions would be enacted with a motor scheme that would be rather different from button pressing if it was the player's in-person actual performance (even full-body in comparison with single finger tapping). Game designers and developers need to approach the problem of how do players learn and execute sequences of inputs that are translated in the correct avatar's actions, but are rather different from them. A growing body of studies in neuroscience is devoted to areas that are relevant to understanding players mediated interaction with avatars. In particular, studies in spatial perspective-taking and embodied cognition allow the analysis of many crucial elements of avatar controlling. I'll apply some of the emerging concepts in this field to a specific videogame genre that is a particularly interesting case study: the fighting games. First, I'll briefly define the genre and analyze how the most successful (and thus played and known) franchises of fighting games best titles meet the definition criteria. Then, I'll analyze the most important features and differences of titles from these franchises that appeared on the market in a comparable time window, focusing on the command system. Then, I'll introduce neuroscientific findings that may be needed for understanding crucial issues in player-command system interaction on the basis of the features described.

DIGITAL FIGHTING GAMES
Digital fighting videogames have been published since the beginning of the videogame industry [3]. Harper [5] offered a working definition of features for games to be classified in the genre: 1-being focused on martial arts-based one-on-one combat, mostly melee 2-including standard attacks and moves that are common among the characters (avatars as called in the fighting game community) and an additional number of special ones specific to each character 3-displaying the parameters of the match graphically on the

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screen 4-being competitive games that is, focusing on winning over the opposing character 5-allowing for multiplayer competition. In addition to these points, some assumptions must be explicated: 6-the gameplay is based on real-time action (i.e. not turn-based gameplay) 7-the focus of the outcome of the match must be the winning or losing (no matter if barely or by dominating – if this is a factor, it must be minor). In light of this definition, I wanted to look at games that fall in this genre, specifically those having a proven success history and are available on the same gaming platform in order to be comparable on common ground. As such, I selected the best-selling fighting games franchises of all time as of data available on June 2017 [16]. They are Tekken (Bandai Namco Entertainment), with 47.6 million sales, Street Fighter (Capcom), with 38 million sales, Mortal Kombat (NetherRealm Studios – Warner Bros. Interactive Entertainment), with 35 million sales and Soulcalibur (Bandai Namco Entertainment), with 13.38 million sales. Games from these franchises are available on the PlayStation 3 (Sony) gaming console platform. A case could be made for inclusion of Super Smash Bros. (Nintendo), with 39 million sales, but the game focus is different from the others in that it requires primarily displacing the opponent, while in the other franchises positioning is part of the strategy but not what declares the winner; moreover, no game from this franchise is available on PlayStation 3. All the selected franchises published their first game more than 20 years ago (Street Fighter in 1987, Mortal Kombat in 1992, Tekken in 1994 and Soul Blade, the first of the Soulcalibur saga, in 1996), with many sequels and chapters still being published to this days (Street Fighter V, 2016; Mortal Kombat XL, 2016; Tekken 7: Fated Retribution, 2017; Soulcalibur: Lost Swords, 2014, even if it is only a single-player chapter). In order to compare games with similar levels of advancement in technology and design, I selected those published in a comparable time-window: Ultra Street Fighter IV (2014, the last revised version of the 2009 Street Fighter IV and the last chapter of the franchise for PlayStation 3), Mortal Kombat (2011, a reboot of the original 1992 game with current technology), Tekken Tag Tournament 2 (2011, a version of the previous Tekken 6 with added modality of team fighting, last Tekken on PlayStation 3) and Soulcalibur V (2012, last multiplayer fighting game from the franchise).

All the selected games fall into the working definition given above. Each of them has some peculiarity:

Being focused on martial arts-based one-on-one combat, mostly melee.

All games are martial arts-based, but some are more inspired by existing techniques (Tekken) and others are more focused on sheer violence (Mortal Kombat). Either most characters within each game (Soulcalibur), or almost none (Street Fighter, Tekken), use weapons. Ranged attacks are a minority of the movelists (the list of attacks and moves that each character can perform). All games are based on one-on-one combat, even if the selected Tekken and Mortal Kombat chapters offer the possibility to use a team of two characters, even if the player controls only one at time ("*tagging*" out one, i.e. making one leave the playground, in order to take control of the partner); however, they still retain the possibility of playing just one character at time and the same control system of the previous chapters.

Including standard attacks and moves that are common among the characters and an additional number of special ones specific to each character

Almost characters in a specific game have a number of commands that perform the same actions, even if the execution may differ slightly. This reduces the players cognitive load, since once the standard patterns are learned, all basic operations for all characters don't need to be re-learned. In addition, each character has a number of unique attacks (and, sometimes, movements). These "special" attacks have command inputs that differ in the sequence of buttons, in timing, in the conditions in which they work and, most importantly, in the effects; this increases the strategic depth of the game.

Displaying the parameters of the match graphically on the screen

The selected games are very similar in the display of the match parameters: the main parameter is the "health" of each fighting character, since one it drops to zero that character is deemed the loser of the game (and the one that made it drop to zero, consequently, the winner). This parameter is displayed as a "life bar" in the upper part of the screen and is depleted when the character is hit, simulating damage being taken. The number of games one in the current match is another parameter that all games display (the winner of the match is, usually, the first to reach 2 out of 3 games). In all games but Tekken, a "charge bar" is used, indicating the access to a larger movelist when the charge reaches certain thresholds (each game has a specific formula to replenish the charge bar and how to "spend" charges). All games have other graphic indicators such as flashings, sparks, visual post-processing effects and other means to display in-game circumstances that are game-specific but not relevant to the current study.

Being competitive games that is, focusing on winning over the opposing character

All games strictly meet this criterion. Some modalities offer other focuses, but are variants of the main game mode.

Allowing for multiplayer competition

All games meet this criterion.

The gameplay is based on real-time action (i.e. not turn-based gameplay)

All games meet this criterion.

The focus of the outcome of the match must be the winning or losing (no matter if barely or by dominating – if this is a factor, it must be minor)

All games meet this criterion. Each game gives players some minor reward for dominating or for winning a close game with no effect on the actual match: in Street Fighter and Soulcalibur the player is given an evaluation and points at the end of the match; in Mortal Kombat the player, once the match is won, has access to a brief window to act cruelly by persecuting the defenceless opponent, such has mutilating or dismembering him or her; in Tekken, if a player wins a game with less than 5% of the health bar all that happens is a voice shouting “Great!” (Soulcalibur has a similar reward as well). In all games winning without being damaged at all gives the player a reward with no effect on the match itself, such as displaying “perfect” on the screen.

LIMITATIONS OF THE MEDIATING INPUT DEVICE

By being all available on the PlayStation 3 platform, all games need to have the possibility to be controlled by the same input device, the DualShock 3 (Sony) gamepad. I’ll use this common device in order to compare the games with as few confounding variables as possible. This device features 4 arrow-shaped buttons on the left placed in a crossed disposition that are reachable with the left thumb, four round buttons with icons on the right placed in the same configuration that are reachable with the right thumb, two analogic sticks, one reachable by the left thumb and one by the right thumb, and four rectangular “shoulder” buttons, two of which on the left and reachable by the left index and middle finger and two on the right reachable by the right index and middle finger. The device also includes two buttons at the center for functions that are not related to the actual gameplay in these games. While the DualShock 3 offers basically 12 buttons and 2 analog sticks as possible inputs, all the selected games use the four arrow buttons on the left to move the character in the virtual space. An analysis of the movement of the characters in the virtual space is out of the scope of this study, but is must be noted that the gameplay of these games happen on different planes (two- or three-dimensional). What follows is the analyses of all games control systems, with a brief note on the operative definition of inputs and commands I’ll use.

INPUTS AND COMMANDS

In this study, I’ll use the term *inputs* to refer to the actions operated on the input device (gaming pad, keyboard, mouse, joystick, etc.) by the player, and the term *commands* to refer to the post-device signals that the game system receives after translating the inputs. Commands have an in-game meaning, that the player may be able to understand and later use. While different inputs can result in the same command, the opposite is not true. Practically, the player needs to understand avatar’s actions that are displayed on the screen in terms of commands (meaning) as well as learn their inputs (executing the command) to execute them. Once the learning phase is completed, he or she will be able to predict what will be the outcome of the inputs in command terms.

An input/command distinction may not be necessary, as games with avatar actions that are randomly mapped onto buttons have a perfect match between inputs and commands and could as such be referred to interchangeably, since a motor scheme directly corresponds to an avatar’s action. However, with more complex systems, meaning to parts of the motor execution, such as buttons or timing, could facilitate the motor scheme storage in memory and later recall: indeed, meaningless information is harder to remember than meaningful information [9], and greater semantic involvement is known to promote remembering [2].

COMPARISON OF CONTROL SYSTEMS

Each game input system converts player inputs in at least two types of commands: the movement commands and the action commands. In general, movement commands (directions) allow for character movement inside the virtual space. Action commands are mostly used for attacks. Standard attacks can be performed by inputting simple commands, like a single action commands or a number of them at the same time. As said, they are common to most characters, usually providing the same effect with only slightly character-specific execution or aesthetic variation. Short, character-specific sequences can be performed by inputting commands sequences with the right timing. Variations and unique attacks can be performed by inputting action commands and directions at the same time, or sequences of one, the other, or both with the correct timing. Other aspects of the control system differ.

Street Fighter

Street Fighter uses a fairly simple command system: commands are either punches or kicks and both vary on three levels of intensity (light, medium, heavy). Generally, light attacks deal little damage but are quick, heavy attacks deal more damage or cover more distance or have some additional effect but are slower or have some other disadvantage such as not hitting nearby opponents; medium attacks are the middle ground. Players need to imagine an attack with a specific intensity in order to enact the correct motor scheme. Many attacks are prolonged, cover more distance, are somewhat empowered or have some additional visual effect the more intense they are (i.e., if the light, medium or heavy button has been used), but they are just variations of one another (Ryu’s Hadouken, a projectile of energy launched form his hands, is quicker when the medium punch is used instead of the light punch, and is made of fire and even quicker when the heavy punch is used). However, many times using one button or another results in the same avatar’s action: many commands have more possible inputs. By using 6 action commands on the DualShock 3 gamepad, at least two commands need to be mapped on the shoulder buttons, thus involving other two fingers in addition to the right thumb and potentially two hands (depending on the configuration). Furthermore, the movelist for each character is rather short, counting a dozen unique moves each, with only some of which varying in intensity. Finally, two of the four directions (toward and away from the opponent) usually don’t modify the attack, so the cases in which this happens are exceptions. Directions are, indeed, mostly used in sequences and combination with action buttons to perform unique attacks altogether (Dhalsim’s teleport is performed by inputting backward, down, backward and down together and the three punches or kicks combined).

Mortal Kombat

Mortal Kombat uses a 5 command system: commands can be punches or kicks and both can be executed with the front or back limb (characters use body positions that face the player or have the back to the player, but their heads are turned to face the opponent); in addition to these, the fifth command is used for blocking, while in other games holding the back arrow has this function. A sixth command is used when playing with two characters for tagging. The approach that is used here apparently maps the avatar's limbs to the four buttons, but it only does so when taking the position into account. Indeed, the characters may rotate their body 180 degrees (keeping the head facing the opponent) in order to have the previously front limbs to become the back limbs and viceversa. The performed actions are exactly the same with both limbs (except for some minor technical difference that is not perceivable) but a movement imagined as performed with the left arm may be executed with the right arm; the same command would be used if it was executed with the left arm and/or imagined with the right arm. By using only 4 attacks commands they may all be mapped on the set of the buttons on the right, thus requiring only one the right thumb to reach, while relegating to another finger the block command (since it can be mapped on a shoulder button). There is no obvious link between inputs and outcome: the game has many projectiles, ranged attacks, teleportation and other elements that are not directly relatable to the front/back aspect (Scorpion spear is thrown with the back hand, but the input requires the front punch input) or, sometimes, even to the punch/kick taxonomy (Sub-Zero projectile, a sphere of ice launched from his hands, is performed by using directions in combination with a frontal kick; ADD). The movelists are rather short, featuring about the same number of moves of Street Fighter, with (usually) no variation in intensity but adding around a dozen character-specific sequences.

Soulcalibur

Soulcalibur approach to the command system strictly adheres to the peculiarity of the game, that is, almost all characters using weapons. Indeed, the 4 commands system includes a vertical attack, a, horizontal attack, a kick and a guard input. The vertical attacks are downward or upward blows that occur on the plane that is being observed by the player, while the horizontal attacks are lateral blows that occur on the depth plane. Directions modify standard attacks in somewhat consistent way: by inputting the direction toward the opponent the blows usually reach further or move the character in that direction, while by inputting the opposite direction the resulting attack will usually be either a more charged or powerful blow or move the character away from the opponent; in the same way, but more consistently, inputting the "up" or "down" direction in combination with attacks buttons (with the correct timing) correspond consistently in jumping attacks or low blows. The vertical/horizontal/kick taxonomy is also used extremely consistently and becomes an easy to learn rule for learning and recalling sequences on buttons on the basis of the action appearance (Nightmare's Brutal Cross is a sequence of two horizontal and one charged vertical blows, and it is performed unsurprisingly by inputting the horizontal command twice and the vertical plus backward commands together once). This should come in handy, particularly since the movelists are huge in comparison with the previously mentioned games, featuring around 90 character-specific attacks and sequences. The 4 commands are easily mapped into the DualShock 3.

Tekken

Tekken uses a command system that maps the limbs of the character on the four commands (plus an additional one for tagging): as such, action inputs correspond to the limb with which the outcoming attack is executed by the character. Action inputs can be performed with the upper or lower limbs and with the left or right side of the body (left arm, right arm, left leg, right leg). However, it is interesting that this system does not match the spatial features as in the Mortal Kombat system. The Tekken command system allows the player to imagine the action performed with a limb and see that action executed with the imagined limb independently from the position of the character. Direction inputs in combination with action inputs have less obvious outcomes, but often the body of the character or the limb used for the attack moves consistently with the direction (Lei's Scythe Kick is a kick executed with the right leg while doing a backflip and is performed by inputting the upward, backward and right leg commands together; Heihachi has a downward fist that is performed by using the downward direction). Since the attacks may use complex animations, it may be difficult to tell if the direction to input is the one where the body moves during attack preparation, while hitting or in the final part of the animation (Xiaoyu has an attack that is performed by inputting the backward direction in combination with the right arm: in the execution of the attack she slaps the opponent with the right hand while making a step toward him or her, but ends back-turned; Anna's Mudslide is an attack in which she brings her left leg behind her in order to bring a powerful kick to the ankles of the opponent: only in the first part the leg is behind here, but the command to make this attack are the downward, backward and left leg inputs). As such, the match between avatar-executed attacks and inputted commands is extremely consistent for action inputs (on par with the Soulcalibur consistency), but less consistent for directions. The movelists, though, are even more deep: while basic attacks are several dozens (around 50 attacks from different in-game circumstances that are common to all characters), the list of unique character-specific attacks and sequences reaches the Soulcalibur for the characters with less moves, but doubles in length regularly (reaching more than 350 attacks in total in some cases).

SPATIAL COMPATIBILITY, PERSPECTIVE-TAKING AND COMMON CODING

Spatial compatibility (spatial congruency in different frames of reference) plays an important role in attention orientation in games [4]. As such a congruent spatial references for the in-game avatar and the out-of-game device should facilitate the control over the avatar actions by orienting the attention to the same space region in the different frames of reference. In other words, if the imagined action is happening on the upper side of the virtual space, a player may be facilitated in enacting motor schemes that require the upper emifield of the device, for example the upper buttons. All the games try to take advantage of the intuitive nature meaning of arrows and matching the frame of reference on the device with the frame of reference on the player by using the left arrowed buttons to control the movement in the space. Characters may face either right or left, and all systems adjust the directions mirroring the laterality when the character changes facing orientation (e.g., a backstep is performed by pressing "left" when the character faces right and "right" when the character faces left). While in Street Fighter and Mortal Kombat the device frame of reference matches what happens on the screen, in both three-dimensional games it also matches the three-dimensional plane (depending on how the buttons are used): in both Tekken and Soulcalibur, the "up" and "down" buttons are also used for sidestepping into the background or moving to the foreground.

However, the mere presence of an avatar makes players adopt its frame of reference [15]. The player looking at or imagining avatar's actions takes the avatar's perspective, projecting the self point of reference into the virtual space, centered on the avatar and matched with its one [14]. The frame of reference (FOR) of the player is called egocentric, any other FOR (such as the one centered on the avatar) is called allocentric [7]. The FOR shifting allows for "seeing with the avatar's eyes", but requires inhibition of the egocentric FOR to avoid interference [6]. Indeed, when face-to-face with someone (player to avatar, for example), egocentric FOR and allocentric FOR don't match: an object on the right in egocentric FOR is on the left in the allocentric FOR. On the contrary, if there is an object on the right in egocentric FOR and it is still on the right in allocentric FOR, it means that the FORs share orientation. This would be the case of a player using an avatar facing its back: they share laterality. By using commands that refer to the anatomy of the avatar and mapping them into different buttons, the Tekken command system promotes a allocentric FOR, as, to a lesser degree, does the Mortal Kombat command system.

FOR-based representation of the space has also been related to social cognition that is, understanding other's minds [13]. However, another important mechanism of other's understanding is the embodiment of their actions into the observer motor system: the observer mentally (and unconsciously) simulates the perceived actions in order to better understand them, in a form of covert action imitation [12]. This phenomenon occurs automatically and independently from the observer's will or even conscious perception [8]. The mechanism at basis of this phenomenon is called common coding [11] and is accounted by the mirror neurons system [12]. Common coding models states that, when we perceive a movement being performed, execute that movement or imagine that movement being performed, a common movement representation is activated in the brain motor areas. This means that perception, execution and imagination of movements (particularly actions) involve a number of brain areas that are shared across modalities and are activates regardless the modality that is the source of activation. Mirror neurons represent the information regardless FORs being taken into account. While a spatial compatibility interference may occur, as in the face-to-face condition, common coding maps onto the observer motor system anatomical – not spatial – information. This is referred to as embodied cognition. Again, it is the Tekken command system that is the best at promoting player-avatar anatomical matching.

Many studies have been devoted to spatial interference with embodied action. Indeed, if any factor affects the activation of a motor representation, such as spatial compatibility effects, any modality that requires that representation to be active will suffer or benefit from it. When an executed movement is congruent with an imagined or perceived one, the execution is facilitated, while when it is incongruent interference occur. The same holds true when permuting the modalities: an imagined movement is harder to mentally execute when performing or perceiving an incongruent movement and easier to mentally execute when the performed or perceived one is congruent; the elaboration (e.g.: recognition) of a perceived movement is harder when the imagined or performed movement is incongruent and easier when it is congruent. Acting on an input device such as the DualShock 3 forces players to limit their motor schemes, especially in comparison with newer full-body tracking solutions, and thus embodiment might not interact with spatial factors. However, further analyses should be conducted in this area, since it seems quite intuitive that the Street Fighter command system is suboptimal in asking the player to map part of the commands, let's say punches, on one finger and the others, kicks, on at least two different fingers. All other games have the possibility to map punches (or weapon usage in Soulcalibur) on upper buttons and kicks on lower buttons, in order to match anatomical configuration. This requires an additional FOR centered on the right thumb: since it reaches the right buttons from a rotation of about 45 degrees, the upper and left action button can be considered upper buttons, and the right and lower buttons can be considered lower buttons. The Tekken system, again, shines in being intuitive: with the thumb FOR, left and right buttons can be identified and anatomically mapped.

CONCLUSION

Neuroscience offers interesting tools between theories, models and empirical findings for understanding player's interaction with fighting games and, more in general with avatars. Furthermore, it highlights design problems for command systems in that even some of the most successful fighting game franchises show features that actively interfere with player decoding, learning and playing the game. Since most of the gaming still happens on devices that force the player to use motor schemes that don't directly match those performed by the avatar, further research seems useful in order to promote the design of better command systems. By addressing brain-related phenomena, however, future research might overcome the entertainment boundaries and impact areas such as exergaming for cognitive and bodily rehabilitation, in which the entertaining aspect becomes the motivational factor that increase adherence to the therapeutic program [10].

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