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Play in video games

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ABSTRACT

Video game play is remarkably ubiquitous in today's society given its recent emergence only in the late 1950s. While this fast evolution could exemplify the power of play, video games exploit but also extend other types of play. Here, we review a classification of the ecosystem of video games useful in the emerging field of the cognitive neuroscience of video games. We then discuss how video games may leverage different play types, considering first locomotor-rotational, object, and social play before highlighting the importance of role, rule, and pretend play in video games. With an eye toward comparative studies of the neural bases of play across species, we discuss whether video games may fulfil the five criteria from Burghardt (2005) to identify play. Finally, in line with play's possible preparatory role for adulthood, we review the positive impact on cognition and future learning of action-like video games. Highlighting that not all video games have this impact, we note more granular hypotheses about the biological functions of play are to be encouraged.

When considering play, it is striking that everyone knows what play is, and yet the neural bases of play remain largely unknown. This state of affairs is surprising as play has been characterized as a brain state that brings along many potential adaptive advantages, from preparation for adult life to refinement of executive skills or the negotiations of role taking. A major barrier to the study of the neural correlates of play is that play is by definition self-initiated and thus not easily amenable to controlled laboratory designs; furthermore, it typically encompasses a rich motor repertoire that demands brain imaging capabilities in freely moving animals. Furthermore, it is associated with such rich behavior, from perception to spatial navigation, decision making to reward, positive emotion to fine motor execution that isolating its neural correlates calls for identifying what may be unique to play above and beyond these varieties of already well characterized brain functions.

In a recent seminal study, Reinhold et al. (2019) trained rats to play hide-and-seek with human experimenters while recoding in frontal cortex. In the *hide* condition, rats learned to wait in one of several hiding places until they be found. In the *seek* condition, rats learned to look for the experimenter in one of several locations. In each case, finding or being found was rewarded through gentle tickling of the animal. This pioneering study revealed neurons in the medial prefrontal cortex that code for the different game events. Yet, how these may be unique to play, or in contrast rather may index the sequencing of complex behavioral patterns remain largely unaddressed.

In a striking twist, video game play appears to offer a swift resolution to many of the technical challenges cited above, from enabling play in static individuals, to allowing for the coding of each and every game events, to being so engrossing that, even under constrained laboratory conditions, the proper level of intrinsic motivation may be reached. Yet, if we are to use video games as the experimental manipulation to study the brain state of play, it is necessary to analyze how video game play may relate to what is defined as play be it in the field of human development (Pellegrini, 2009) or that of comparative ethology (Burghardt, 2006b). To this end we first describe the rich ecosystem of video games, then address how different types of play (locomotor, object or social) may be implemented in video games, before discussing the distinctive value of role playing, pretend play and rule play in video games. Finally, we turn to the five criteria proposed by Gordon Burghardt and collaborators to classify a behavior as play in comparative studies, and ask whether they may apply to video game play, before reviewing the literature documenting the cognitive advantages and the brain changes video game play, or at least some form of it, affords.

1. The ecosystem of video games: a primer

Video games are electronic, interactive games which place the player in alternate worlds ruled by principles and constraints that may go beyond those found in the real world. Following Crawford (2003),

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games are entertainment pieces that are interactive, have goals, challenges, and conflicts, and allow for attacks between players. In contrast, he defines interactive experiences with no goals as toys, experiences meant for beauty rather than money as art, challenges with no competitor as puzzles, and conflicts with no attacks as competition, rather than games. Differences between these categories are now blurrier, but they help set aside video games from content watching or from real-life simulations often used in education, such as flight simulators or laparoscopy simulators.

Video games arguably offer the most common form of “play” in today’s society. The video game industry has been growing, reaching 192.7 billion USD in sales globally in 2021, with half of sales being on mobile platforms (McDonald, 2023; newzoo, 2023). Compared to other types of entertainment, revenues for video games remained higher than those from media services (such as Netflix or Disney+), theme parks (IAAPA, 2018), digital music streaming, and cinema combined (PwC, 2022). People report playing video games brings them joy, helps them escape everyday life, and acts as a source of stress relief (Desai et al., 2021; Pallavicini et al., 2021; Roy and Ferguson, 2016); additionally, many also use it to socially connect, whether it is online or in-person (esa, 2022). In doing so, it seems to serve similar key functions of play behavior.

Yet, the extent to which video game play qualifies as play behavior requires careful consideration. Video game play was first developed by adults for adults. From their creation in the 1950s, video games were exclusively accessible to educated adults with access to computers. With the arrival of arcade video games, generally stand-alone, coin-operated machines housed in amusement arcades, video game play began to attract a section of the adolescent population. Then, with the emergence of dedicated home consoles and personal computers, video games began to be played more by adolescents, with the development of video games appropriate for young children only occurring at the turn of the 21st century. Thus, although video games are now also played by children, the average age of a US and European gamer in 2021 was 32 years old, with 76–80% of gamers being 18 or older (esa, 2022; ISFE and EGDF, 2021). In France, the average age was 39 years old, with 88% of adults (18+) having played video games (SELL, 2022). This state of affairs stands in contrast to play behavior being typically more common in the young than in adults across the animal kingdom.

Such a stunning adoption for this form of play is likely rooted in the large variety of games, as the industry caters to individuals of different age, sex or play styles. Classifying video games into categories or genres has been useful to organize a growing library of video games leading to an early classification of video games into genres such as Space Invaders-type, Asteroids-type or maze. As new games became more complex and innovative, partially due to better hardware and software capabilities, new genres arose such as first-person shooter, adventure, and role-playing games. Today, this ecosystem is richer than ever as we define here nine different genres, and a supra-categorization that has proved useful in guiding the research on the cognitive impact of video game play (distinguishing action-like video games, and non-action-like video games). We recognize, however, that game genres are becoming more and more hybrid with both single game titles offering different play modes in distinct genres as well as new genres emerging that are more and more intertwined, a testament to a fast-changing ecosystem (Dale et al., 2020). Moreover, we warn the cognizant reader that what is defined as action-like in the cognitive literature is not fully aligned with what the video game industry defines as action video games for marketing purposes.

1.1. Action-like video games

Action-like video games, as defined in the cognitive literature, have the particularity of making heavy demands on different forms of attention in real time. Typically, these video games challenge divided attention, meaning the play requires one to track many targets moving

quickly and independently, or to react to many enemies, while simultaneously also requiring states of highly focused attention, such as precisely locating a sniper or a health pack, or avoiding a collision in a driving game. Four genres belong to the action-like video games: First- and Third-Person Shooter, Action-Role Playing Game (RPG) / Adventure, Sports/Driving, and Real-Time Strategy / Multiplayer Online Battle Arena.

1.1.1. First-person shooter and third-person shooter (FPS/TPS)

First and third-person shooter games, also termed Action Video games in the cognitive literature, are at the core of the action-like video game classification. They are typically war, zombie or survival video games such as installments of the *Call of Duty* franchise (Infinity Ward et al., 2003) or the *Half-Life* series (Valve, 2020). Such game play focuses on using firearms or long-range weapons to chase and kill enemies, while ducking, running, or transforming to avoid being destroyed. The only difference between first- and third person shooters is in whether the player sees through the eyes of the avatar, or whether the player can see their avatar from an outside view. These video games, mostly designed for young adults, are played at a fast pace and require one to make quick, precise decisions while attending to multiple objects on the screen. These video games can be played with other players or with bots (AI controlling the other characters in the game), either as partners or competitors. This video game genre has been the most studied in the cognitive literature where they are also known as “action video game” (note that what the video game industry defines as action video game is a different category) and associated with enhancement of attentional control (Bavelier and Green, 2019; Bediou et al., 2018). Throughout this review, we will refer to this category as “shooter video games.”

1.1.2. Action-role playing game (RPG)/adventure

In this category, players usually go on quests, which tell them what to do and where to go, while engaging in combat along the way. These video games exist in both first-person view and top-down (bird’s-eye) view. Action-RPGs include role-playing game components, where players can track metrics or statistics on their players, impacting their ability to fight against enemies of varying strengths and abilities. Action-RPGs also tend to put an emphasis on the evolution of the story through the character’s eye, while adventure video games are more about exploration or puzzle solving. Overall, this category places significance on having a compelling story, having dialog trees with non-playable characters, and exploration. In the Action-RPG video games of the *Elder Scrolls* series (Bethesda Softworks et al., 1994), players advance in a high fantasy world, encountering mythological creatures and using magic. In the Adventure game *Myst* (Cyan, 1993), players solve puzzles on a mysterious island. The combat engagement encountered along the way does have some of the attention-challenging game components found in shooter games (first- and third-person shooter as seen above); hence, their classification as action-like.

1.1.3. Sports/driving

These are simulation sports where players would generally look to engage in a fast-paced, attention-demanding sport such as car racing or ball games (*F1* (Codemasters et al., 2000), *Forza* (Turn 10 Studios and Playground Games., 2005) or *FIFA* (Extended Play Productions et al., 1993), *NHL* (Park Place Productions, 1991), *NFL 2K* (Visual Concepts, 2004), *NBA 2K* (Visual Concepts, 1999), as example video games series, respectively for Formula 1, car racing, soccer, ice hockey, American football and basketball). Players can play with their favorite athlete, and can either strive for realism, by going to the extreme of buying or building life-like rigs of a car to feel as if they were in a real racing car, or on the contrary, go beyond reality such as *Mario Kart* (Nintendo EPD et al., 1992) driving game with the ability to throw banana peels on the road to slow down opponents. These video games are generally played from a top-down view, while driving video games are played from the point of view of the driver in their seat, or the back of the vehicle. Racing

video games tend to require fast decisions with players dividing their attention between staying on tracks and the position of their competitors. *NBA 2K* (Visual Concepts, 1999) and *FIFA* (Extended Play Productions et al., 1993) video games tend to be slower but require distributing attention simultaneously to the whole set of players on the field, requiring even greater division of attention. These demands in attention explain why these games are action-like. Accordingly, a simulation sports game that does not challenge divided attention such as golf or swimming would not be included in this genre.

1.1.4. Real-time strategy / multiplayer online battle arena (RTS/MOBA)

Real-time strategy video games involve planning with multiple units and resource management under time pressure. Video games in this category unfold in real-time where all players play at the same time, so both the ability to react quickly and to consider the details of one's, and others, play positions and resources remains key. These video games are played with a top-down view for a better global view on the map. Key interactions involve gathering resources, constructing buildings, defending the base, attacking enemies, and controlling an army of characters. Rather than controlling multiple units, Multiplayer Online Battle Arena focuses on having the player control a single character only, but in coordination with teammates and against a competing team. Attention to teammates as well as competitors' position and action is key, requiring both divided attention between these as well as a high focus on one's action within that rapidly unfolding battle. In the *StarCraft* franchise (Blizzard Entertainment, 1998) made of real-time strategy video games, players can play with one of the three available species and play against the others, while in *League of Legends* (Riot Games, 2009) players control a single champion amongst 162 available ones and is played with 2 teams of 5 players each competing against one another.

By enforcing attention to several players and multiple tasks, these games require swiftly dividing attention between objects or between tasks, as the game situation evolves rapidly, again implementing some of the same mechanics as shooter games.

In the rest of the paper, the term action-like video games will be used for the four game genres listed above. This terminology should not be confused with the wider definition of "action video games" used by the video game industry. The latter generally corresponds to any video games where the focus is on controlling a character's physical actions, going through levels to fight enemies in real-time and where hand-eye coordination and reaction time are key. This includes shooter video games and Multiplayer Online Battle Arena video games described in this section, but also fighting games which, despite being fast, do not always put the same demands on divided attention and swift changes in attentional states.

1.2. Non-action-like video games

This second larger category has in common lesser demand in flexible allocation of attention under time pressure, and thus lesser load in the switching of tasks and/or of attentional states. This may be the case because players only have one type of action to do at a time, or players have to be fast but repeat the same action or sequence of actions again and again, or because they can go at the speed of their choice to complete their next moves.

1.2.1. Turn-based / non-action role-playing / fantasy

This genre of game is similar to Action-RPGs except that combat here is turn-based, and thus does not put time pressure on the player, letting each player take as much time as they like at each step. In doing so, it also stresses much less changing between different modes of attention. In the original *Pokémon* video game series (Game Freak & ILCA, 1996) such as *Pokémon* red and blue, the player advances on a map, catching and training Pokémon and fighting against other trainers. During combat, players must wait for their opponent to finish their moves before playing. During their turn, there is no time pressure, and the game could

be paused indefinitely until the player decides on their attack.

1.2.2. Turn-based strategy / life simulation / puzzle

Similarly, to the previous category, these video games do not put the players under time pressure. Instead of taking the time to take in the narrative, players generally make use of this time for more analysis and strategizing. By being less demanding in terms of swift attention allocation and decision speed, *The Battle of Polytopia* (Midjiwan AB, 2016) is an example of such video games that could be compared to *StarCraft* (Blizzard Entertainment, 1998) in regards to the variety of actions such as collecting resources, training units, and sending them to combat, but at a much different pace. In *Polytopia*, players receive a set number of stars at each turn, depending on the growth of their cities. The stars can then be used to perform a limited set of actions. In life simulations, players control a simulated environment (a city, theme park or hospital) or an agent (humans, dogs or cats). The game focuses on the relationships within the ecosystem it offers, letting players either experiment or take action towards achieving goals. In video games of *The Sims* series (Maxis, 2000), players control a household of one or multiple sims, and although they are given no specific goals, can choose to develop their Sims's skills, advance their career, form deep relationships while taking care of their natural needs such as sleep, hunger and hygiene.

In puzzle video games, players interact with either abstract puzzle pieces, or with realistic objects in the predefined game space. The goal is to solve problems with the tools made available within the game. These types of video games usually involve point-and-click, drag-and-drop, along extensive planning. *Candy Crush* (King, 2012) is a famous example of a tile-matching puzzle game, where the goal is to move colored pieces on a board such that three or more of the same pieces are matched, to remove them from the board. *Lemmings* is a hybrid between a puzzle game and a strategy game where players are tasked to guide a group of lemmings to an exit using specific skills in order to advance through obstacles. Although these games require to sustain attention over time, they do not challenge real-time proper attention of allocation as action-like games do.

1.2.3. Music games

These video games generally involve responding to visual cues appearing in rhythm, for the duration of a song. This can be done using the default buttons of a device (*Taiko no Tatsujin* (Namco and Bandai Namco Studios, 2001), or through dedicated reproduction of instruments (*Guitar Hero* (Harmonix et al., 2005), *Donkey Konga* (Namco, 2003), etc.). These video games involve rapid finger or foot movement, requiring extremely good timing and coordination as players have to follow the rhythm of the music heard. While highly demanding in sustained attention, the focus remains strictly on the sequential flow of cues, with no need for major shifts in attentional allocation or state.

1.2.4. Other

This final category is for any other video games that may not fit into the categories above. This includes fighting video games, but also any reproductions of casino, card or board games, and many party video games.

In fighting video games such as the *Street Fighter* series (Capcom, Dimps & Arika, 1987) – *Tekken* series (Bandai Namco Studios and Namco, 1994), *Mortal Kombat* (Midway Games et al., 1992), combat between two or more players is usually implemented following different martial arts styles and movements. Players program ahead of time sequences of combat moves that then unfold at high speed. Players watch and can intervene to add to these combat sequences, a process that, while requiring high speed, maintains attention highly focused on just one of the two fighters. Such fighting games thus put lesser load on divided attention and possible switches in attentional states than other action-like genres. Some fighting games such as *Super Smash Bros* (HAL Laboratory, 1999) do allow for more than two players as well as other sources of peripheral distractors. Although attention still remains highly

focused on the players in combat, such fighting games do require some distributed attention; accordingly, fighting games are sometimes referred to as action-like video games in the cognitive literature. We will refrain from using this terminology.

Card games, board games or casino-style games are simple to pick up, mimicking known real-world games. They typically involve short sessions and are aimed at being accessible to the general audience.

Finally, but importantly for its consequences on attention, as games are played through smaller and smaller devices (laptop, tablet or smartphones), their ability to load on divided attention gets reduced. This is why even first- or third-person shooter video games when played on smartphones are not considered as action-like games. Now that we have situated the diversity of video games and suggested a possible classification around the attentional requirements of such play, we turn to the three pillars of play - locomotor, object and social play- and discuss how these may be instantiated in the context of video game play.

2. Locomotor, object and social play in video game play

The literature on play identifies different categories of play (Bekoff and Byers, 1981; Fagen, 1981; as described by Burghardt, 2006b). For example, in animal play, the distinction is made between locomotor-rotational (dogs chasing one's tail), object play (cat playing with yarn), and social play (lion cubs play fighting). While each of these can be divided into subcategories, the distinction between them is not always clear and the categories can be blurred, yet some major fundamentals distinguish them. In human play, the categories considered are finer, distinguishing between roughly 10 different categories of play (Parten, 1932; Piaget, 1962; Smilansky, 1968; as described and amalgamated by Burghardt, 2006b): Sensorimotor (infant reaching for and manipulating objects), Construction (creating towers from building blocks or sculpting shapes with modeling clay), Parallel (when multiple children play alone but stay close to one another), Simple Games (Peek-a-boo between an adult and a baby), Pretend (Drinking tea with stuffed animals), Sociodramatic (Role playing, playing doctor and patient, pirates), Rough-and-tumble (chasing and wrestling), Language (infants babbling, jokes), Rule (Games with agreed rules, including turn taking, penalties, played in pairs or teams), and Ritual (Repetitive social routines). Below we first discuss how video games have capitalized upon the three fundamental categories of play found across the animal kingdom, then in Section 3, we turn to categories video games have heavily exploited, namely role play, pretend play, and rule play.

2.1. Locomotor-Rotational play in video games

This type of play is typically solitary with the animal executing a sequence of movements, such as leaping, running, prancing, in the absence of any contextual cues indicating that such a behavior is appropriate. The movements are often exaggerated in form, with abrupt reversals of direction and typically involve whole body movements rather than fine and precise movements. As Burghardt (2006a) says, "The gambols of foals released from barn stalls into a field, and the rush of schoolchildren onto the playground during recess are readily appreciated examples of locomotor play". The function of locomotor play is often seen as a form of rehearsal for situations concerning hunting, mating, escaping or asserting dominance, in line with the view that such play may serve a motor learning function to augment fitness in future adult situations (Power, 2000).

Locomotor play is probably the least represented in video game play. Indeed, video games are typically played seated, with a limited set of motor inputs either through a keyboard and mouse, a joystick, dedicated console controllers, a touchscreen or combinations of buttons, rotary knobs and trackballs. This limits the dictionary of actions relevant to the game to manual ones. Even more problematic, the game play mechanics implemented by game designers typically restrict actions to a limited set; thus, the choice of actions is constrained in a way that very much

departs from what is seen in physical locomotor play.

As most of the actions made by a video game player will likely be done in response to a stimulus specially designed to prompt them to act, guiding the player toward what is expected from the game, video game stands in rather stark contrast to locomotor-rotational play where movements are executed without such external prompts. In another sharp departure with animal locomotor play which typically concern the whole body, video games call for sequences of fine motor movements that are unlikely to be part of a repertoire of fundamental motor sequences of our species rehearsed during play. Rather, it seems video games exploit here the great neuroplastic capabilities of motor control. Indeed, with each game comes a slightly different mapping of motor actions to control movements in the game. When the movements to be controlled are of one's avatar, it could be viewed as locomotor play. In *QWOP* (Foddy, 2008), a critically acclaimed game despite its notorious difficulty, players control an athlete in the goal of going as far as possible without falling. The only controls are the QWOP keys, mapped to the runner's thighs and calves. The Q key moves the right thighs forward and left thighs backwards while the W key does the opposite, and it is the same for the OP keys controlling both calves. The learning challenge is likely similar to that of learning how to walk on stilts, but now through a manual interface controller. In *Kreedz Climbing* (ObsessionSoft, 2017), another movement based game similar to parkour, players use keyboard control to direct their avatar through intricate parkour-like body movements. In *Lone Echo* (Ready at Dawn, 2017), players become service android in space and first need to learn how to move in zero gravity. They can do so by moving their controllers to grab onto objects, push themselves off walls, or by using their wrist-mounted thrusters. The complexity and pace needed can go well beyond what is typically seen during physical manipulations.

More recently, the inclusion of more sensors has widened the range of possible motions, though even in these cases, movements are always part of a fixed dictionary outside of the control of the player and mostly goal directed. Within these constraints, some video games exploit locomotor play. The first instantiation is arguably *Dance Dance Revolution* (Benami, 1998). Players stand on a dance platform composed of four arrows going in each of the cardinal directions. Players need to hit the arrows with their feet at a fast pace in a specific sequence dictated by the game according to a series of cues displayed on the screen, resulting in dance-like movements. Sensors under each arrow allow direct feedback in the game world. The possibility for video games to engage the whole body was highlighted by the success of the *Dance Dance Revolution* series (Benami, 1998) with more than a hundred different releases across multiple systems, formats and world regions. Exploiting recent technological advances in motion capture systems and now virtual reality headset, more video games are designed to do so. Exergame and fitness video games are such examples. Like *Dance Dance Revolution* (Benami, 1998), those video games invite the players to put themselves in specific positions or body poses, requiring more energy expenditure than your typical seated video game play. By adding an external color webcam, the *EyeToy* (Sony Computer Entertainment, 2003) allowed for video games where the player's body position could be tracked to play Whac-A-Mole or clean sequences of soapy windows with their arms. Other systems of motion sensing were introduced, starting with *Wii game console* and its controller the *Wiimote* (Nintendo IRD, 2006), then with the *PlayStation Move* (Sony Interactive Entertainment, 2010) and *Microsoft Kinect* (Microsoft, 2010) where players could play tennis, baseball, bowling. Using a balancing board, *Wii Fit* (Nintendo EAD, 2007) invites players to practice yoga and balancing exercises with a closed-loop system integrating image and position sensors from the board to allow real-time feedback. With such feedback, the player can fine tune poses or achieve greater balance. More recently, *Ring Fit Adventure* (Nintendo EPD, 2019) as in high demand, particularly at the beginning of the Covid-19 pandemic given the stay-at-home requirements. Using the *Nintendo Switch Joycon's system* (Nintendo PTD, 2017), the game proposes to perform physical activities using a Pilate ring-like object and a leg strap

by sensing the position of the object and the amount of strain exerted on the ring. Breaking incoming blocks with lightsabers in virtual reality (VR) in *Beat Saber* (Beat Games, 2019), or shooting at enemies and dodging bullets in *Pistol Whip VR* (Cloudhead Games, 2019) and *Superhot* (Superhot Team, 2016), all require full body motion while the real-time feedback is key in maintaining the activity playful.

Finally, thanks to more agile VR and motion capture systems, video games are evolving toward experience-based play, where the player is wearing a headset and immersed into a physical space where she sees herself moving from room to room in the VR world as she moves physically. Real objects or others are present and can be interacted with in space. Other examples in virtual reality exist which are not meant as video games but are viewed as playful. In the dance piece in virtual reality *VR_I* by Cie Gilles Jobin and Artanim (2017), groups of 5 participants at a time embark in a virtual reality experience, wearing a headset and multiple motion capture trackers. In contrast to most video games, this experience does not require participants to interact with elements within the “video game”. Rather, throughout the 40 min of the experience, the 5 participants see virtual avatars dancing, as well as themselves and their peers moving in real time through avatars, leading to an almost inevitable session of playing and dancing together. Thanks to precise motion capture and enough freedom given to the participants, this type of experience is an example of how seemingly unplanned, playful behavior can emerge possibly thanks to locomotor-rotational play. Even after 40 min of time, the players are usually still excited with the novelty, though it is unclear whether this would last once they get used to it.

Of note, these more embodied experiences, which allow for locomotor-rotational play, have hugely benefited from the latest technological advances in body tracking. Some such examples are full body tracking, precise hand-held tracker, tracking of player’s position in 6 degrees of freedom including translation in a 3D space as well as rotation of the player’s point of view. All these advances enable precise tracking of the player and her effectors in the virtual world – a key requirement for locomotor-rotational play to be even possible in virtual environments. As these technologies improve, this type of game play is likely to evolve and allow for locomotor play to be spontaneously expressed as well as to integrate object play. This can already be seen in video games such as *Half-Life: Alyx* (Valve, 2020) where players, thanks to a VR headset, do not just navigate the space but also interact with objects such as playing the piano, drawing with markers, or moving on monkey bars, if they choose to. It remains that all these instances of locomotor-rotational play in the virtual world are contingent on cues and goals; allowing for them to occur spontaneously is one of the promises of online virtual worlds and of a possible Metaverse (Girvan, 2018; Shin and Kim, 2022).

2.2. Object play in video games

Object play consists in behaviors when animals interact and manipulate objects beyond mere “specific exploration” (Berlyne, 1960) and where their movements seem to provide no immediate benefit. It is also referred to as diverse exploratory play (Drickamer et al., 1996), solitary object play (Power, 2000), or sensorimotor play (see later discussion in Burghardt, 2006b). Interestingly, it is also called predatory play when seen in carnivorous species, such as when a cat chases a bouncing cork or “plays” with a live mouse. Similar to locomotor-rotational play where the behavior may play a role in augmenting fitness in future adult situations of escaping or hunting, object play may also resemble courtship, nest building, sexual behavior or antipredator responses, and can be reminiscent of foraging movements. Examples of object play include horses playing with balls and sticks, which can be similar to the behavior of pushing non-edible material away for access to better grass; Komodo Dragons playing with buckets, Beluga whales (Delfour and Aulagnier, 1997) and bottlenose dolphins blowing bubbles then kicking or swimming through them. In children,

object play has been extensively studied; one distinctive form of object play is construction or building play where parts are assembled to produce a novel object. LEGO, DUPLO, and log building sets have all become classical examples of such object play. In adult humans, object play often takes the form of toy play, though it is often dismissed as motivated by nostalgia or viewed as goal-driven with creative, artistic or productive goals. Such play can often be described as collecting or engaging in a hobby (Heljakka and Harviainen, 2019). Examples include the assembly of Gundam model kits, the *Millennium Falcon* in LEGO with its 7541 pieces, or the customization or collection of designer toys such as the *MUNNY* and *DUNNY* collections of Kidrobot.

In a way, when it comes to video game play, the bulk of it consists in object play. Video games offer a window into a virtual world, where the player interacts with a variety of objects, be it avatars, health packs, building blocks, or falling zoids. Unlike in physical play, the interaction is mediated through different knobs and buttons (game controllers, keyboard and mouse, joystick, etc.), rather than through direct physical contact with the object. But as in physical object play, these interactions may require precise combinations of fine movements to interact with the object. In *Balance* (Cyparade, 2004), players control different types of balls via mouse and keyboard, and have to carefully move them along a course without falling off the path. In *StarCraft* (Blizzard Entertainment, 1998), players can control hundreds of army units, as when children play with toy soldiers, leading attacks, preparing defenses, gathering resources, in addition to interacting with buildings and selecting upgrades; proficient players can get up to 150 actions per minute. They know exactly which actions are needed, when, and are able to execute at breathtaking speed. As is the case with physical object play, such activities appear to serve no apparent immediate benefit at first sight; this very state of affair has often led to the characterization of adults engaging in video game play as merely wasting their time.

It should be made clear that, in most video game play, the enticing part of the play is not so much in the learning of the perceptuo-motor skills needed to interact with the objects. Accordingly, game designers go out of their way to make such controls as intuitive and transparent as possible. Good game design seamlessly guides players where they should go. If players do not know what to do, or repeatedly go in the wrong direction, they may quit out of frustration. For example, ensuring players can move their avatar through corridors, stairs or small treacherous paths in third-person point of view video games is not a given. Most novice players tend to find themselves climbing walls or going backwards. Game designers spend several game levels to onboard players to teach them the necessary motor control skills for a smooth navigation of their avatar in the game world. They give players just enough information to keep them interested without overloading them with currently irrelevant commands. Thus, the play value in video game is rarely seen in the perceptuo-motor aspect of the interaction (except for a few game titles whose goal is *exactly to exploit loco-motor play as discussed in the previous section*), but rather in the discovery of how one’s manipulation of objects in the game changes the state of the game world. As we saw before, the dictionary of actions in Tetris (Pajitnov, 1989) is quite limited, but Tetris’ play value comes from giving entire freedom to the player as to which of these actions to take when, allowing for an extremely large space of possible action-reaction around the falling object or zoid. From that perspective, video games can augment the possibility of object play in many ways, beyond what is possible from our world physics. In *Portal* (Valve, 2007), players must teleport through inter-spatial portals between two planes and manipulate objects, in order to get through a level. Both *Superliminal* (Pillow Castle Games, 2019), and *Monument Valley* (Ustwo Games, 2014) rely on surreal perspective optical illusions to solve a level.

Arguably, the most representative examples of object play in video games are Sandbox games. Those are the types of video games where the player is allowed a great degree of creativity to interact with objects, often without any predetermined goal. This type of environment can leave room for more voluntary behaviors to occur, exempt from any

external directions. The bestselling video game to date, *Minecraft* (Mojang Studios, 2011) is a sandbox game where players evolve in a 3D world made of cubic blocks. They can extract materials, build tools, machines, buildings, or anything that they can imagine. The game has no specific goal other than rewarding achievements. What players end up doing mainly depends on their selected game modes, the three main ones being Survival, Creative and Adventure. In Survival mode, players have to forage for resources to build items and shelter in order to keep good health levels and survive through enemy attacks. In Creative mode, players have access to all resources, do not have to worry about their survival and can directly edit the environment by creating and destroying elements of the environment. While the first mode emphasizes a rather action and adventure experience, this second mode allows the players to be creative, build large structures, cities, and to let their imagination run wild. Finally, Adventure mode is intended to be played on custom maps created by other players, similar to quests. Those maps can be created in Creative mode, though they are more commonly built using third party tools. Creators have been able to curate a diverse range of content, from puzzles, to adventure, role playing, and even parkour video games, where similar to the real-life sport, players need to go through obstacles or jump from platform to platform, to reach their target destination. This mode is more limiting than the others, to ensure that players do not mistakenly or maliciously break the quest and spoil the adventure. It is possible that the enormous range of activities offered by *Minecraft* in addition to object play, is the very reason why it is a best-selling game and one of the most played to date (List of best-selling video games, 2023).

Indeed, video games that allow for rich object manipulation and building activities have encountered huge success. In fact, in other video games, players are often seen deviating from the originally intended game play to engage into building activities, or object play. For example, video games of the *Sims* series (Maxis, 2000) are designed as life simulation game, where players, through their *Sims* characters, pursue career and relationship goals in the virtual world of the game. Yet, many players are found spending more time house building and interior designing in the *Sims*, engaging into object play, rather than the social play these video games aim at emulating. Similarly, tycoon games such as installments of the *Rollercoaster Tycoon* series (Sawyer, 1999) had players focused on roller coaster building and attraction theming, deviating from the more general goal of managing a profitable theme park. Thus, video games not only exploit object play, but interestingly even when not at the core of the play experience, object play is seen by players as a highly desirable feature of the video gaming experience.

In all, object play is at the core of video game play, from discovering how to interact with novel objects to freely building imaginary worlds with pre-specified sets of objects or primitives. Video games offer the advantage over the real world, that they allow for a wide diversity of objects, not only in forms but also function enabling an almost infinite possibilities of interactions relatively cheaply.

2.3. Social play in video games

Social play is play directed at others, with classic examples of chasing in juvenile rhesus monkeys (Symons, 1978) and play-fighting in juvenile dogs (Bekoff, 1974). As Burghardt stated in his 2006 book (2006b), play fighting has been the most studied type of animal play with 82.5% of articles from 1984 to 1994 being totally or largely about play fighting (Pellis and Pellis, 1998). Although early video games were all solo players, it can be argued that video games owe much of their appeal to having successfully integrated social play in the play experience they deliver. Video games have done so in a way that exploits more varied forms of social interactions than just chasing or fighting, in no small part thanks to a great reliance on verbal communication.

Chasing is rather rare in the video game play space, likely because the act of chasing one another can quickly become boring, especially when video games typically aspire to facilitate the act of moving (as

discussed before). Some chasing video games exist though; many rely on horror elements based on hunting or being hunted, such as *Secret Neighbor* (Hologryph, 2019), *Dead by Daylight* (Behavior Interactive, 2016) and *Friday the 13th: The Game* (IllFonic and Black Tower Studios, 2017). The mechanic of chasing is used in many player-versus-player shooter video games, where all players share a single map, and have the goal of finding and killing as many people as possible. The difficulty is in finding the other player, then being able to kill them, rather than only being about the pursuit of someone in sight like it is in animal play. Some video games include a chasing mechanic such as the racing simulation game *Asphalt Urban GT* (Gameloft, 2004), where players can choose to be cops chasing racers, or racers chased by cops, depending on the game mode. Other video games include a mechanic of escape from an enemy, like in *Prince of Persia: Warrior Within* (Ubisoft Montreal, 2004) where the player has to escape from enemies in order to reach safety. Another distinct example are video games of hide and seek such as *Prop Hunt* where hiders become props of the environment, then need to be found by the seeker. Play fighting and rough-and-tumble play is more common in video games and embodied in the popular fighting game genre (see Section 1.2.4 for a description of the genre).

Social play has become a strength of video game play, especially when it comes to pretend play and role playing. Video games are able to support these activities in ways that would not be easily reproducible in real life, at least not without much effort, either in terms of imagination, or actual set and prop building. Players seek social validation in playing, as they can become savior of a kingdom, a well-respected wise elder, the defender of the weak and oppressed, a bomb “Defuser”, a spy or vigilante. Video games give players the opportunity to take on many roles, and then witness the impact of their action on the state of the video game world, literally in front of their eyes rather than just in imaginary pretend play. Playing with other people was already possible with the very first video games such as *Pong* and *Tennis for Two* (Atari, 1972; Higinbotham, 1958). The rise of single player games is likely owed to these delivering a sense of social interactions through intelligent agents controlled via artificial intelligences - or algorithms passing as intelligent. Later, during the first decade of the 21st century, the possibility of interacting with other human players online has led to a real boom of the industry as exemplified by Massively multiplayer online video games (or MMO). They are video games gathering a very large number of players going up to the million. Players can interact with one another and can cooperate or compete against one another. Although many styles of MMOs exist, Massively multiplayer online role-playing games (or MMORPG) are possibly the most popular type with video games such as *World of Warcraft* (Blizzard Entertainment, 2004) or *Eve online* (CCP Games, 2003) being among the most famous examples. In these video games, players create their avatar, explore the world, fight against enemies, and complete quests. Although players can play by themselves, the game actually encourages players to collaborate with others in order to complete missions, achieve goals that would be unattainable on their own, or simply giving them protection against other players that may be interested in their possessions. In *World of Warcraft* (Blizzard Entertainment, 2004), this is done by joining guilds, some of them with more than 150 members, allowing them to be stronger, have access to more items and skills, as well as having a sense of camaraderie. In *Eve Online* (CCP Games, 2003), players are also encouraged to take on specific roles with the societal organization of the world, some players taking smuggler jobs, others dedicating time to craft weapons, or mastering the control of space fighters to defeat opposing clans in massive space battles, the largest player-vs-player battle involving 8825 players over the course of 14 h. As in any social group, the most active groups would require good leadership and organization. Interestingly *World of Warcraft* became of interest to epidemiologists when a bug led to the creation of an in-game pandemic known as the “Corrupted Blood Incident” in 2005, where players infected by a negative effect - a debuff - could spread the effect to people in their close proximity (Corrupted Blood incident, 2023; Debuff, 2023).

Social play, similar to what is witnessed in animals, can also trigger self-handicapping whereby if one of the players is too strong, they may choose to self-handicap to give their play partners a better chance to win or at least survive, ensuring that they remain in the game longer. In video games of the *Super Smash Bros* series (HAL Laboratory, 1999), the goal is to knock one's opponent off the stage. To do so, players can use attacks, inflicting damage and with varying levels of knockback - or how far the attack sends its target. As the damage meter of a player goes up, the chances of being sent off the stage by an attack increase. Players can set a handicap level affecting the knockback, to attain a better balance between players of different levels. This translates into more damage received and less damage dealt by the more skilled player, compared to the less skilled one. In the later releases of the series (Brawl, 2008; SSB4, 2014; Ultimate, 2018), handicaps correspond to the initial damage meter of the player, making them more susceptible to being sent off the stage. These types of fighting video games usually involve pitting characters that have different moves and characteristics, thus with definite strengths, weaknesses, and specific moves to execute and play the character optimally. A stronger player can self-handicap by selecting a character that is objectively weaker than the character of their opponent, or they can also select a character with which they are not used to playing, making their moves less optimal.

Finally, a common feature of social play in animals is role reversals as when two dogs play fighting quickly and frequently take turns in being the attacker or the defender. Role reversals in video games appear to be less common. They do occur but over longer periods, once a round is over, and may never occur for some players. In some games, role reversals are simply enforced by the game. In *Among Us* (Innersloth, 2018), the imposter is automatically designated by the game at the start of each round. In games where multiple characters are available, players tend to have their preferences and stick to a specific character or avatar. Some single player games invite players to swap roles within a game session, either to access new storylines through different protagonists (Quantum Dream, 2010; Rockstar North, 2013) or by having the main character transforming or shapeshifting to acquire new abilities (Konami Computer Entertainment Tokyo, 1997; Nintendo EAD, 2000).

In sum, social play has become a central element of video game play design, even if it was largely absent in the early forms of video game. As for object play, social play can be augmented in extremely creative ways owing to the virtual nature of the video game play experience.

3. The value of role playing, pretend play, and rule play in video games

Although locomotor, object and social play were discussed as three well circumscribed types of play, most forms of play are likely to combine all three play types. As they evolve, the boundaries between different video games genres and style of play are becoming blurrier, merging the multiple known types of play in humans. Moreover, a distinctive feature of video game play is that it demands that physical actions be translated into a virtual world, rather than the physical one. From that point of view, video games fully exploit the cognitive capacities of humans. In doing so, the resulting play may be both rooted in play behavior as described in the animal literature but also extending it in more cognitively and socially demanding directions.

3.1. Role playing, pretend play, and rule play

We briefly turn to role playing, pretend play and rule playing, whose elaborate ways seem quite distinctive in humans.

3.1.1. Role playing

Role playing is often ascribed to children as they engage in social games in which the players take roles and then negotiate taking turns in these roles. The game of tag is a classic example common in most cultures where one child assumes the role of the chaser and the other one

the role of the chasee, until the roles reverse. Of course, such role playing can take more complex forms, such as when a child assumes the role of the doctor and the other one that of a patient. Interestingly, the ability to assume interactive, cooperative, or dramatic roles is viewed as predictive of later cognitive ability (Ruben et al., 1983). Finally, a feature of role play that is highly common is role reversal as in games of tag where the chasee becomes the chaser. In adult human play, role-playing games also exist in the form of tabletop role-playing game (TRPG) or live action role-play (LARP). In both types of play, players take the role of a character, respectively through discussion or by physically acting and dressing up as the character. Such play requires at least one external person to set the rules and supervise the progress.

3.1.2. Pretend or make-believe play

Pretend or make-believe play is often associated with role playing. In its most striking form, an object is given an entirely different set of qualities requiring a clear dissociation between "real" and "imaginary". Classical examples of pretend play in children are talking to a doll, using a stick as a horse, or pretending that the floor is lava. In humans, it is easy to identify when a child is engaging in make-believe play thanks to language or body gestures. In their review, Weisberg (2015) presents different forms of children pretend play, starting from 18 months old, a toddler pretending to be talking on the phone by putting any object to the ear - object substitution-. Children from 3 to 5 making up invisible imaginary objects or even imaginary friends, pretending to be a doctor or playing with dolls or figurine fighting or drinking tea, then later playing with peers in a world of good guys vs bad guys. Pretend play in children has been shown to be correlated with some aspect of the theory of mind (Dore and Lillard, 2015; Goldstein and Winner, 2011; Schwebel et al., 1999; Youngblade and Dunn, 1995; as cited in Weisberg, 2015), which is the capacity to infer others' mental states and thus enabling one to entertain mental states other than their current ones. Pretend play has also been linked to counterfactual reasoning, or the capacity to imagine different outcomes based on what-if scenarios (Buchsbaum et al., 2012; Wente et al., 2022).

3.1.3. Rule play

In rule play, players share an understanding of the constraints under which the play is valid or accepted. Those play activities with rules and expectations go from the simplest peek-a-boo where infants enjoy watching an adult's face appear and disappear, to more complex games such as Chinese Chess (or Cờ Tướng), which similarly to chess, is a strategy board game representing a battle between two armies composed of pieces with specific moves.

Although less common in animals, rudimentary forms of role play and pretend play have been documented. Role reversal is commonly observed in play chasing and play fighting where two or more animals would take turns being the chaser or the chasee. In terms of role play, it requires the animal to play the role of either attacker or defender, regardless of their actual strength. For pretend play, there has been evidence of baby chimps taking care of a dead stick, as her mom would take care of her while sick (Parker and McKinney, 2000). Rule play is likely more structured in humans than in other animals, as one can appreciate if reading through the 245 pages of the *National Football League, 2022* official playing rules for American football (*National Football League, 2022*). Role reversals and self-handicapping as young animals engage in social play does exemplify that players follow certain rules of engagement or at least have implicit expectations about the rule that governs the social interactions, a feature that is in particular important for the play event to continue. Beyond role reversals and self-handicapping, Manitzas Hill et al. (2023) have reported a variety of games that are repeatedly observed in belugas, from tug-of-war to playing with a gate. The fact that such games were repeated successfully in spite of participants requiring to cooperate, could be an indication that participants had an understanding of the shared objectives or rules. In all, while these three categories of play can be found in the animal

world, play in humans can be far more complicated.

3.2. How do video games leverage role, pretend, and rule play

Here we review how video games make extensive use of role-playing and rule play and discuss how more pretend play is emerging as sandbox games have become mainstream.

3.2.1. Role playing in video games

It could be argued that video games build on a drive for role playing, that appears more important than what one could have predicted before their advent. Being virtual, video games allow game designers to create almost any kind of scenario, realistic or imaginary. Video games are all about players pretending to be a character in that novel game world with designers working hard to ensure make believe. These are key components for players to enter the video game and be attracted to its magic circle (Jaakko, 2012; but see Consalvo, 2009). This is all the more enticing when the rules are different from real life. This is why storytelling is so central to game design (Dickey, 2005). Video games, in particular Role-Playing video games, can facilitate role playing, pretend and fantasy by placing players in a new world, having them unfold a story at their own pace, allowing them to develop their characters and abilities, discover and explore tangible environments that can go from the most life-like simulation to a fantasy world of wonder. Rather than relying on their own imagination, players are led through the game design to discover a large quantity of content in real time, both about their own avatar and the world they inhabit (Freed, 2013).

Game designers have long known that allowing players to customize their avatars – through choosing their gender, eye color, body appearance, clothing and the like – goes a long way in retaining the player in the game world (Birk et al., 2016; Birk and Mandryk, 2019; Kao and Harrell, 2018; Turkay and Adinolf, 2015). Why? Because it seems to satisfy a rather basic need for playing a role and broadcasting to all what that role is. As games allow players to interact as an avatar, different from their real “self”, avatar customization has become central in allowing the player to shape their character in the game the way they like, creating themselves literally a *Second Life* (Second Life). On this online platform – which creator maintains is not a video game – users could create an avatar, interact with others, and discover a virtual world. At its peak, the platform had one million regular users. These are particularly advanced in Role-Playing video games, though can also be found, to a lesser extent, in many other types of video games. This is in stark contrast to non-video game role play such as children playing pirates with sticks, or even tabletop role-playing games, where players have to imagine the setting themselves, or where a gamemaster is required to advance the story and possibly compute points and describe which next move may or may not be allowed.

In most games, the path offered to the players is usually interesting and diverse enough that there is no need for reciprocity between players, and thus role reversal tends to be rare as compared to its prevalence in other forms of play. In cooperative multiplayer video game, role reversal is certainly possible, yet it appears from our knowledge of game play that players rarely choose to do so, signaling players tend to select and stick to some preferred roles. Asymmetric games that are non-cooperative tend to favor such reversals as by design different mechanics and end game goals are assigned to different roles, and thus changing roles allow further exploration of the game space, either by choice or by assignation from the game. Even in this case, it is our observation that role reversals tend to happen only occasionally as the time spent in one role would last longer than it is the case in animal play-chasing or play-fighting, a reversal generally only happening at the end of a round rather than within the same “play bout”.

3.2.2. Pretend play in video games

One key aspect of pretend play is producing one’s own imaginary actions, characters, stories, or worlds, and possibly embarking peers

along the journey. In many video games, all these components are already created in advance by the game designers and do not require any input from the players. Where pretend play in human non-video game play requires creation and imagination, this is often not necessary in video games. One exception exists in Sandbox games. As described in Section 2.2 on Object play in video games, players are relatively free to build what they want in sandbox games. They can create their own environments and rules of engagement within the game, as well as eventually share the game world they have built with other players. Thus, it could be argued that sandbox games allow for some form of pretend play to be expressed.

3.2.3. Rule play in video games

Another characteristic of video games is that despite being quite rule-based, the rules evolve as the game unfolds allowing for an extremely rich set of possibilities. The many seasons of Call of Duty do not all implement the same rules of play; this is very unlike in sports or at chess where the rules stay unchanged from one game to another. In the video game world, most game titles evolve their rule from one season to another, keeping a similarity only in name title. The novel challenges that the new season of the game requires to master, thanks to implementing new rules, make it a rather different game play experience. Again, such a state of affairs likely owes to the extreme cognitive fitness of humans and the appeal of having to discover and learn new rules to prevail in the game. This is, as far as we know, unheard of in animal play.

The rules embedded in video game environments are quite different from the implicit rules that may govern animal play, such as for example those that have been described during play fighting in rodents. Rules are so pervasive in video games that different gaming etiquettes are now current practice within the gaming community. For example, while many game designs allow for players to break a rule, this can be frowned upon by peers. Examples of etiquette are to not “steal” a care package from a teammate in Call of Duty, to not write in all caps in chats as it is considered as shouting online, to remain polite towards one’s opponents etc. (Gaming etiquette, 2023; Jack, 2013).

It should now be clear, given how they are developed, that the play activities proposed by video games have differences in nature as compared to what play research defines as play, in both non-human and human. The extent to which such “guided” play fits the definition of play remains an open question. Below we consider this question exploiting the ethological approach of Gordon Burghardt to review how video game play may fit the 5 dimensions this author proposed to define an activity as play.

4. Comparing video game play to other types of play

A major challenge in the study of play concerns the type of behavior that qualifies as play. Is play similar or different to exploratory behavior? When an animal expresses a form of curiosity, is it play? Can we determine when a snake or a spider engages in a playful activity? In *The Genesis of Animal Play* (2006), Gordon Burghardt made a seminal proposal: he introduced five different criteria that have to be simultaneously met for a behavior to qualify as play. These 5 criteria include that (i) “the performance of the behavior is not fully functional in the form or context in which it is expressed; that is, it includes elements or is directed toward stimuli that do not contribute to current survival.” (ii) “The behavior is spontaneous, voluntary, intentional, pleasurable, rewarding, reinforcing, or autotelic (“done for its own sake”).” (iii) “It differs from the “serious” performance of ethotypic behavior structurally or temporally in at least one respect: it is incomplete (generally through inhibited or dropped final elements), exaggerated, awkward, or precocious; or it involves behavior patterns with modified form, sequencing, or targeting”. (iv) “The behavior is performed repeatedly in a similar, but not rigidly stereotyped, form during at least a portion of the animal’s ontogeny.” (v) “the behavior is initiated when an animal is adequately fed, healthy, and free from stress (e.g., predator threat, harsh

Table 1

Game genre classification as per the cognitive literature (for full detail see <https://www.unige.ch/fapse/brainlearning/vgq/>).

Game genre	Examples
First-/Third-person shooters (FPS/TPS)	Call of Duty, Half-Life, Apex Legends, Halo, Overwatch, Counter-Strike,.
Action-Role playing game (RPG) / Adventure	Elder Scrolls, Myst, The Witcher, Mass Effect, Fallout 4, GTA, Assassin's Creed, Tomb Raider, The last of us,.
Sports/Driving	F1, Forza, FIFA, Mario Kart, NHL, Need for Speed, Rocket League,.
Real-time strategy (RTS) / Multiplayer online battle arena (MOBA)	StarCraft, League of Legends, Warcraft I, II & III, Dota, Command & Conquer, Age of Empires, Pokémon Unite,.
Turn-based / Non-action role-playing / Fantasy	Pokémon, World of Warcraft, World of Warcraft, Final Fantasy, Divinity: Original Sin II, Chrono Trigger,.
Turn-based strategy / Life simulation / Puzzle	Civilizations, The Sims, Candy Crush, Hearthstone, Roblox, Among Us, Restaurant Empire, Puzzle Quest, Bejeweled, Solitaire,.
Music	Guitar Hero, Beat Saber, Dance Dance Revolution, Rock Band,.
Other (includes mobile and browser games, fighting games, etc.)	Super Smash Bros, Tekken, Street Fighter, A Dark Room, Wordle, Skribbl.io

microclimate, social instability), or intense competing systems (e.g., feeding, mating, predator avoidance). In other words, the animal is in a “relaxed field”. This characterization of play has allowed the field to make major advances, especially when it comes to the evolution of play across the phylum. Here we review these 5 criteria when applied to video game play.

Interestingly, in the same way it was noted by Burghardt (2006b) and collaborators that play comes under many forms, there also now exists such a wide variety of video games as reviewed in Section 1 that video game play should not be understood as a unitary concept. Video games as a medium allow for a wide range of content, mission statements and affordances, that permits and possibly even augment our everyday life experiences. As such, they may provide fun, entertainment, excitement, enjoyment, but also learning, artistic expression, political expression, social exploration, or rote memorization. Thus, it is to be expected that not all video games will satisfy play criteria, especially the more serious, narrative or artistic based video games. Yet here we review how some video games may satisfy play criteria, or how they may depart from fulfilling such criteria.

4.1. Criteria 1: limited immediate function

The initial idea behind this criterion was that the observed behavior was not fully functional and had seemingly no particular use other than engaging in play, setting it apart from any specific behavior such as foraging, hunting or courting. As a result, engaging in such behaviors would be costly to perform, either in terms of energy, or because it could expose the player as prey.

Video game play is seen as a form of leisure and entertainment that is of limited immediate function, except possibly bringing pleasure and joy to players as play typically does (esa, 2022; Oliver et al., 2016; Ritterfeld and Weber, 2006). Video game play makes no direct contribution to either the fitness of the individual in the moment or the survival of the species. We will review in the next section whether, in the long-term, video game play may result in behavioral advantages, but video games are certainly mostly perceived as an activity of limited immediate function.

4.2. Criteria 2: voluntary activity - done for its own sake

Behaviors identified as play do not involve any external stimuli, other than the environment being appropriate for play, through the presence of objects or play partners. The animal appears to engage in the

activity on its own volition, for no apparent reason, but arguably the reward of the experience it provides. In animals, social play is known to be rewarding. The concept of reward has been proposed to be separated into three components: “liking”, the actual pleasure from the experience; “wanting”, the motivation to seek the reward; and learning; with neurotransmitters of all three being implicated in social play behavior (for a review, see Trezza et al., 2010). In contrast, excess “wanting” is problematic and linked to addiction (Berridge and Robinson, 1998, 2016).

Video games, at least the ones meant for entertainment, are clearly played voluntarily, and are a highly rewarding activity. Here we are talking of video games that players are willing to pay for and to spend their free time on, at the expense of other possible activities. Such a voluntary choice makes them akin to animal play. Strikingly, however, external rewards are a key component in video game design in a way that does not parallel animal play (Birk et al., 2016; Phillips, 2018).

The extent to which the video game reward mechanics may distort the voluntary aspect of play requires diving into more details. Wang and Sun (2011) describe four attributes of reward systems in video game play that could have different influences on different players. The first one is social value and consists in gaining social status through game play. This ranges from games recording high scores on arcade machines, so that the name of the top players be displayed on the screen, to avatar customization with rarer custom items being a way to recognize the more advanced players. To the extent that there is social value in play, this mechanism, although quite different in its implementation in video games may be shared with play more generally. The second one is the timing of rewards, with most video games distributing rewards at several different, inter-laced timescales, from in the moment to the end of the round with final scores. In *Guitar Hero* (Harmonix et al., 2005), for instance, players have to press on buttons corresponding to the visual cues appearing on the screen. The game rewards players who manage to complete streaks of ten correct hits by giving them a score multiplier, making their final score much higher. Other video games may include other visually appealing displays or even pop-up messages saying, “good job” or “perfect”, with satisfying effects. While less well documented in animal play it is possible that the execution of behavioral patterns during play also results in rewards with varying timing, from the satisfaction of having executed one of the components of the behavioral pattern to that of having completed the whole sequence of actions, especially during social play. The third one is the possibility to collect and review assets, achievements or trophies. In the Pokémon (Game Freak & ILCA, 1996) series, this is done through receiving badges for each major gym boss that is defeated. Such back-tracking in time seems pretty unique to video game play. The fourth ones are those that may help advance the player in the game, in the form of new weapons, objects or possibilities. More recently such rewards have been packaged in loot boxes that can be received as a reward, or that can be purchased with (real) money. As they open their boxes, players receive a number or randomly selected items, usually with a thin chance to earn very rare items. Although highly successful in generating revenues for the companies, such practices have been criticized due to their similarities to gambling. Again, such reward mechanics is unlikely to be found in animal play.

The few studies of video game reward structure already indicate that such extrinsic reward systems interact with player's intrinsic motivation, at times enhancing it but also possibly blunting it. Some intervention studies have been done to explore possible links between playing video games and the brain's reward system, although more studies are required (Gleich et al., 2017; Lorenz et al., 2015; Watanabe and Sasaki, 2015). To the extent that efficient game design leverages conditioning, reinforcement and rewards to shape the players' behaviors and encourage them to play, all such external components to the player not only depart from the apparent, rather pure intrinsic motivation present in animal play, but also directly impact the expression of such intrinsic motivation (Ryan and Deci, 2020).

4.3. Criteria 3: incomplete and exaggerated behavioral patterns

While the two previous criteria could be an indicator of intention or motivation, this criterion describes what play behavior may be expected to look like. At least in animals, the play behavior is expected to incorporate behavioral patterns that will be part of the behavioral repertoire in adulthood. These patterns during play are typically incomplete or executed in an exaggerated fashion.

Exaggerated or incomplete motor patterns during video game play is rather unlikely given video game play limits behavioral patterns to rather high dexterity and extremely precise motor controls. Players learn behavioral sequences that they can eventually execute repeatedly to perfection if relevant to win or fun enough to perform. Where exaggeration or incompleteness may be found is in the cognitive or emotional aspects of the video game play, but not so much in the behavioral patterns executed. For example, that characters can die and respawn is certainly an exaggeration compared to everyday life, and one that clearly signals a play world, distinct from the real world. It may be argued that to the extent that exaggeration and incompleteness are important to signal that the activity is within the realm of play and to enable role-switching, as when incompleteness of an attack allows the attacked to become the attacker, then the cognitive and emotional exaggerations and incompleteness that video games story arcs enable are akin to the ones expressed mostly motorically in the animal kingdom. This proposal would benefit from further studies.

4.4. Criteria 4: repeated performance

In animals, the play behavior is performed repeatedly, usually in bouts or rounds. One way to differentiate non-play from play, is to identify the amount of time spent on the behavior (Byers 1999a), and the number of bouts or repetition throughout. This criterion is especially useful to distinguish play from more anecdotal reports, or from more common behaviors of explorations.

As seen earlier, video games used to be very simple with limited and rather repetitive mechanics, such as *Tetris* (Pajitnov, 1989), where geometric shapes need to be placed on a board as they are falling. The only change throughout the game is in the speed of the fall, increasing the difficulty. The shapes or zoids are limited to a set of twelve ensuring some situations will repeat. Such repetition may explain why players report “seeing” shapes at sleep onset or even throughout the day (as described in Stickgold et al., 2000). In the music game series *Taiko no Tatsujin* (Namco & Bandai Namco Studios, 2001) where players simulate playing a Taiko drum, the only controls correspond to tapping in response to a blue or a red cue in rhythm. Repetition is thus one of the core features of video game play.

As video games have become more complex, they feature more variability in difficulty and types of actions, allowing them to maintain the interest of the player for longer than mere repetition would. Even so, they do often include repetitive mechanics. Casual games are one such example, being both quite simple and extremely repetitive. This is the case of tile-matching video games such as *Bejeweled* (PopCap Games, 2001) or *Candy Crush Saga* (King, 2012), a highly successful game title where players move tiles such that tiles of the same type can align into a line of usually at least 3 units. The game continues as the aligned items disappear, until the player reaches a certain score or until the board is eventually cleared. Another known example is *Cookie Clicker* (Thiennot, 2013), where the only action the player can take at first is to click on a giant cookie, granting them one cookie for each click, the cookies being the in-game currency. By accumulating enough cookies or in other words clicking repeatedly, they can later purchase upgrades, for more efficient outputs per click or even automatic collections of cookies.

Cookie Clicker likely had a strong influence in the emergence of a new game genre: idle games. Here the main mechanic is to grind, by starting to click or tap repeatedly on the screen to collect units, to a point where the automatic collection of units may end up being more efficient than

clicking. All the players can do now is to wait until they have enough units to purchase the next upgrade and be idle -hence the name- or alternatively purchase add-ons with real life money or watch ads for bonuses (Ian Bogost, 2010; Playsaurus, 2014; Thiennot, 2013). The surprising appeal of these video games may come from the relative ease to play, entirely based on repeated actions, making for a quick distraction. Other larger video games can include similar mechanics of grinding or repetitive behavior, sometimes linked to the production of resources necessary for the construction of better buildings, units or materials in another part of the game. In some games, the repetition of the task is offered to the player as a soothing behavior. In *Stardew Valley* (ConcernedApe, 2016), players can spend all their time farming or fishing just for the sake of it. In the *Sims* (Maxis, 2000), players can repeatedly train a skill of their Sim, such as cooking, logic or creativity, for the Sim to be better at a task, or to unlock new actions. In all, even when extremely diverse, video games fundamentally build on repeated behavior.

4.5. Criteria 5: relaxed field

Play behavior is more likely to be initiated when the basic needs of the animals are met. It is well known that animals that are well fed, comfortably warm and in a relaxed state, play more than others (Groos, 1898; Hornaday, 1922; Pereira and Fairbanks, 1993; Spencer, 1872; as compiled by Burghardt, 2006b; Brooks and Burghardt, 2023; Burghardt, 2014). As well-maintained captive animals usually do not have to worry about their survival, this may be why play is more common in captive animals compared to their wild counterparts (Burghardt, 1988). Of note, play can also be stress-reducing as when bonobos play to better cope with competition and social tension, or when common marmosets' self-scratching behavior - a stress indicator - is reduced after play (Norcia and Palagi, 2011; Palagi, 2023; Palagi et al., 2006). In line with this view, cortisol concentrations in dogs were reported to decrease after play and affiliative behaviors (Horváth et al., 2008).

The same could be said of humans, where the intuition is that individuals only look for video game play, once they can ensure their most basic needs are met. Indeed, video games appeared quite late in human evolution, and did so in communities where people had reached a good enough quality of life that their basic needs were met. If going along Maslow's hierarchy of need, video game play, like any other form of play, may be placed far from the first pillar of physiological needs, though it could be argued to fit on the second one of safety needs and health. As discussed for animal play, video games may not just be played in a relaxed field, but in turn also provide a way to release stress (Desai et al., 2021; Pallavicini et al., 2021; Roy and Ferguson, 2016). Video game play has been proposed to promote well-being and positive mood, through socialization or through coping, with escapism, distraction, or a sense of control not met in real life (Bowman and Tamborini, 2015; Ferguson and Olson, 2013; Nijhof et al., 2018; Reinecke et al., 2012; Whitaker and Bushman, 2012). Measures of cortisol levels in tournament chess players indicate, as in the dog example discussed above, that cortisol level are reduced through gameplay, at least when the challenge matches the player's level. When facing a much stronger opponent, cortisol level tended to rather rise after the bout of chess play (Tozman et al., 2017). Such a U-shape curve underscores a rather complex relationship between stress and play, with play at times being realized through an intense, risky or competitive behavior that itself may be stress-inducing in the moment. The physiological impact and evolutionary role of experiencing stress as part of play remains, however, largely unexplored.

5. When video game play may prepare for future learning

Play is most common amongst immature animals; this finding has been at the source of a variety of hypotheses about the very functions of play. Three early theories, as summarized by (Burghardt, 2006b) are:

“surplus energy” (Spencer, 1872), “instinct-practice” (Groos, 1901), and “recapitulation” (Hall, 1905). The thought process behind the “surplus energy” theory was that “higher” animals have on one hand more efficient ways to survive and on the other hand, an underuse of certain behavior faculties, resulting in the possibility, or rather the need, to relieve oneself of that surplus, in ways that would be relevant to the animal, within their characteristic behavioral repertoire. In the “instinct-practice” theory, Groos (1901) argued that with more intelligent animals able to use their intellect rather than their instinct, good instinct mechanisms would be lost, and thus, play would be a way to perfect instincts, necessary for the development of the individual. In his view, play originates from the need to anticipate and prepare for the future. Finally, the “recapitulation theory” proposed play as being the residue of irrelevant behavior that were once necessary in the past of a species. Although it is not useful for immediate needs, Hall (1905) argued that it remained necessary for “perfecting the organism”. The first two have in common that the behavior seen in play remains relevant to each species’ future serious behaviors, and the latter two have in common that play somehow prepares the animal for the future.

More recently alternative views proposed that play allows the animal to fine-tune the key cognitive processes that make executive functions, including working memory, inhibition and cognitive flexibility (Baarendse et al., 2013; Bell et al., 2010; as reviewed in Pellis et al., 2014, 2018). In doing so, it acts as a preparation for future learning, possibly augmenting the ability of the young to adapt and survive to a greater diversity of situations.

Since the inception of video games, there has been much controversy about the usefulness of spending so many hours on such a sedentary, and sometimes lonely, disconnecting activity (Gee, 2003; Greenfield, 2011; Jarvis, 2017; Prensky, 2006). Is video game play a mere waste of time serving no useful function, or could there be behavioral advantages to playing video games? A growing literature documents the beneficial aspects of video game play be it on cognition, health, education, or mood (Dale et al., 2020; Mayer, 2019; Pine et al., 2020; Russoniello et al., 2009). This trend is not only visible through the fast-expanding number of journal articles considering game-based interventions but also through the inception of new peer-reviewed journals around that topic such as Games for Health or JMIR Serious Games to cite a few.

In the domain of cognition, where video game play may lend behavioral advantages in future situations (Anguera and Gazzaley, 2015; Bediou et al., 2018; but see Sala et al., 2018), one major caveat is of note – cognitive enhancements through video game play appears only robust if the video game is part of the action-like video game play genre (and in particular shooter video games). This fact highlights that while all video game play is highly playful, not all video game play equally impacts cognition. Interestingly and unlike the case of nonhuman play and non video game play, these benefits have mostly been documented so far in young adults, and not children, likely due to most of the action-like video game being not suitable for children (for meta-analytic studies, see Bediou et al., 2018, 2023).

5.1. The impact of action-like video game play on cognition

Over the past 20 years, a literature has emerged focusing on action-like video games, (with most studies focusing on first- or third-person shooter video games). Meta-analytic work, mostly carried in young, college-age adults, documents an increase in cognitive skills in self-declared action-like video game players (Bediou et al., 2018, 2023; Powers et al., 2013). That is, young adults who play action-like video games more than 3 h per week and have done so for at least the past 6 months show enhanced cognition by about $\frac{2}{3}$ of a standard deviation, a medium effect size. This is akin to a change score from a mean of 100 to a value of 110 if cognitive skills were measured with an average score of 100 and a one-standard deviation value of 15 (Similar to the distribution of IQ scores in the population). Among the cognitive skills documented to be improved are visual skills, such as an enhanced ability at reading

the fine print on medication package inserts, better task-switching skills such as more gracefully switching between tasks or multi-tasking, better mental rotation skills or improved working memory skills (Cardoso-Leite et al., 2015; Chopin et al., 2019; Feng et al., 2007; Podlogar and Podlesek, 2022). Too few studies exist, however, concerning higher cognitive skills such as planning, reasoning or problem solving to conclude as to their impact following action-like video game play, or other forms of video game play for that matter (Parong et al., 2021). It is therefore important to remember that the improvements noted after action-like video game play mostly concern lower cognitive functions, from perception to executive functions. These skills have been measured through performance-based assessments, often computer-based tasks but also paper-and-pencil ones, recording reaction times, eye movements, percent correct decisions or the like (Chisholm and Kingstone, 2012; Dye et al., 2009; Green et al., 2010; J. Li et al., 2022). Thus, performance enhancements have been quantitatively demonstrated, in contrast to qualitative changes as when asking players how they perceive their own cognition through self-report questionnaires.

Although interesting, the finding that self-declared action-like video game players are endowed with better cognitive skills does not answer the key question of whether action-like video game play causally induces enhanced cognition. It could be that action-like video game players tend to have better cognition to start with. To answer that question, intervention studies are needed whereby participants are assigned to either a group asked to play an action-like video game or to a group asked to play a control video game. Such control video games are also selected from commercially available entertainment video games but among non-action-like video games. Such games include puzzle games, turn-based strategy games or social simulation games to cite a few genres. By measuring performance on a cognitive skill, such as mental rotation, before and after the required video game play, one can evaluate the cognitive impact of action-like video game play. If action-like game play enhances cognition, it is expected that individuals trained on the action-like video game will improve on the cognitive construct measured before and after their game play training more than those trained on the control games. Importantly, such intervention studies typically require tens of hours of video game play, through short, repeated daily and distributed over weeks training (Bediou et al., 2018; Stafford and Dewar, 2014). Such long duration can be sustained thanks to the capacity of video games in keeping players highly motivated throughout the gameplay (Pasqualotto et al., 2022). In the meta-analytic work carried, the shortest training duration was of 8 h and the longest one of 50 h (for examples of intervention with more than 30 h of training, see Bejjanki et al., 2014; Green et al., 2010; R. Li et al., 2009, 2010; Green et al., 2012). Such training is also best administered through short, distributed practice of about 20–60 min per day for 5–2 days per week over a period of several weeks. Note that in such studies participants are recruited so as to not be novice at video game play, but yet not play more than three hour per week of any game genre within the past 6 months.

Meta-analytic work of such intervention studies indicates that action-like video game play is associated with improved cognition by about $\frac{1}{3}$ of a standard deviation, in comparison to playing other video game genres (Bediou et al., 2018, 2023). Although relatively modest in size, this effect is within the range of the different cognitive interventions discussed in the literature, as for example physical exercise (for a review, see Erickson et al., 2015) or mind-body training (Chan et al., 2019; Tang et al., 2015). A distinctive feature of this work is that the effect of video game play is not measured just after the video game play activity, whereby arousal could have led to a fleeting improvement in performance. Rather, a period of at least 24 h and often much longer is enforced between the last game play and the assessment of the cognitive skills of interest, ensuring durable changes, for the better, in cognition are highlighted.

5.2. Brain mechanisms at the root of enhanced cognition

Improving cognition across a relatively wide array of skills remains relatively rare in cognitive training. Those training documented to do so typically target executive functions. Bavelier and Green (2019) have proposed that action-like video games are specially well designed to enhance cognition because they train attentional control, one central executive function, for the better. Accordingly, brain imaging studies document a reorganization of the fronto-parietal network of attention, including the middle frontal gyrus and the parietal cortex, and its connectivity with the temporo-parietal junction, a key region in regulating between top-down and bottom-up attention. Connectivity changes in that network has been linked to a lesser false alarm rate in an attention-demanding task (Föcker et al., 2018). The view is that by training not only the ability to focus on the features of the environment and those of the task that may be useful to perform well, but also the ability to ignore sources of noise or distractions, action-like video game play trains players to more readily adapt to new environments and learn novel tasks. Accordingly, Zhang et al. (2021) have shown that after 45 h of action-like video game play (over a period of 10–12 weeks), participants learned faster a novel perceptual task and a novel working memory task as compared to those trained for 45 h on non-action-like, control video game play. In the perceptual task, participants were asked to indicate whether a patch of oriented lines faintly presented and masked was tilted left or right from a 35-degree imaginary angle. By giving feedback as to whether performance was correct on every trial, participants could learn to make that discrimination over several days of practicing. The rate of learning was found to be faster in action-like video game trainees than in control trainees. In the working memory learning, participants were asked to perform an N-back task. Participants are presented with stimuli one at a time at a relatively slow pace of one stimulus every second and asked to first detect when a stimulus just repeated in the sequence, called a one-back repetition. Then when at ease with this task, they were asked to now detect when a stimulus repeats, however not just one-back, but two-back (as in —3 to 6–3–...). Once at ease with this two-back task, they were asked to now detect when a stimulus repeats three-back (as in 3–7–4–3–), etc. for a total of 7 sessions over 3 days. Again, the rate of learning was found to be faster in action-like video game trainees than in control trainees. Thus, playing 45 h of action-like video games seems to lead to faster future learning of tasks participants are not familiar with, in at least the perceptual and executive function domains. Similar facilitation of future learning also seems to apply to the sensori-motor domain and aspects of spatial memory (Gozli et al., 2014; L. Li et al., 2016; Page et al., 2017; West et al., 2018). So far, all these experiments have been carried out in young adults. By allowing for faster learning of novel, unknown tasks, action-like video game play is seen as fostering learning to learn, or future learning.

5.3. Game mechanics responsible for enhanced attention in action video game play

A key question concerns what in the gaming activity allows for such impact on cognition, attentional control and future learning. As the intervention studies considered all contrasted action-like video games to other video games, just engaging in a playful activity does not seem sufficient to guarantee such impact. Rather, by analyzing and contrasting different video game genres, Cardoso-Leite et al. (2020) have proposed that action-like video games likely derive their positive impact on attentional control by aligning some key mechanics during the game play. These involve first and foremost putting a load on divided attention, requiring the player at all times to monitor different parts of the screen as well as shifting their attention between different features of the scene such as when looking for a sniper versus searching for an active killer bot. Combined with such a load on divided attention, is the need to switch attentional mode on demand as the game requires to shift from

visual search mode to engaging in a highly focused, aiming mode during fighting. Swiftly switching between modes of divided and focused attention is likely to train cognitive flexibility, a key executive functions component. Last but not least, action video games put a heavy load on pacing or the need to execute actions or take decisions under tight time constraints. In other words, the player needs to feel under time pressure; not that absolute speed is of the essence, rather a game that feels fast to a 60 years old may feel slow to a 20 years old. Pacing just means the game needs to be designed to apply some time pressure on the player, in a way that is balanced with their skill level. Finding such a balance is at the core of what game design is about, in a way that departs from juvenile game play in the wild.

In closing, similarities and differences between action-like video game play and juvenile play in the wild are worth stressing. First, intervention studies with action-like video games have been exclusively carried out in young adults (typically 18–35 years of age) that are past the typical sensitive period for fine tuning of sensori-motor, cognitive, social or emotional functioning that juvenile play has been hypothesized to refine. Second, all action-like video game intervention studies contrast two equally playful forms of game play as the experimental group is asked to play action-like video games and the control group to play equally entertaining and commercially successful non-action-like video games. The extent to which action-like video game play in young adults leverage some of the same mechanisms associated with enhanced plasticity and learning during juvenile play is, however, worth considering. By targeting the dorso-lateral prefrontal and parietal cortices, action-like video game play enhances executive functions and in particular attentional control, these same functions also hypothesized to be fine-tuned during social play in juvenile animals (Pellis et al., 2018). A potentially fruitful avenue for future neuroscience studies would be to characterize in parallel studies the neural mechanisms by which both juvenile play and action-like video game play may shape the neural architecture for future motor, cognitive or social functioning.

6. When video game play becomes unhealthy

Here we have described the positive outcome of engaging in some video game play, given that it is used in a responsible manner. But video game play can certainly become associated with extremely poor outcomes such as Internet Gaming Disorder. While recommendations focusing strictly on screen time fail to capture the need for better mental health support that is signaled by individuals suffering from Internet Gaming Disorder (Bediou et al., 2020), the reviewed research on the benefits of action-like video game should not be taken as an invitation for binging. Quite to the contrary, intervention studies show short, distributed practice over a few months is best to enhance cognition, with massed practice leading to lesser impact (Bediou et al., 2018). Additionally, it is worth stressing that video game play is counterproductive if it takes away from other activities, whether school work for academic performance, especially during week days (Gnams et al., 2020; Hantanto et al., 2018; Weis and Cerankosky, 2010) or actual physical play and the risky, exploratory behaviors so crucial for healthy development (Hansen Sandseter et al., 2023). An important point in future works will be to unravel how some extrinsic rewards in video game play design may result in a play experience that deviates from the spontaneous, intrinsically driven, more healthy behavior, play is meant to be.

7. Conclusion

In this review, we asked whether video games are a form of play as defined in the comparative work of Gordon Burghardt and colleagues. Going through the large diversity of existing video games, we investigated the known diverse types of play – locomotor, object, social – to highlight where video games may or may not be aligned. While many aspects of video game play appear to have a direct comparison to animal and children play, major differences remain, although these may be

explained by (i) the limited role locomotor-rotational play can have in video games given today's technological limitations, and (ii) the central role of cognition in video game play, likely owing to the advanced cognitive, language and social abilities humans are endowed with. Another key divergence is in how much external stimuli and rewards are used to guide and motivate players to immerse themselves in the video game play experience, where such carefully guided external prompts are almost non-existent in spontaneous play in animals or in children. Finally, we show how when used in a responsible manner, even what is often referred to as mind-numbing video games – in particular action-like video game play – can have a beneficial impact on attention, cognition and possibly future learning. In closing, we highlight that in contrast to play in the animal kingdom or in children, which is most prevalent in juveniles and becomes rarer in adulthood, video game play remains by and large an activity mostly relevant to young adults and older children – possibly re-enacting in these less playful stages of life, the more raw, enticing form of play that is typical of very young ones.

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Declaration of interest

Daphne Bavelier is a cofounder of Akili Interactive, Boston, MA. Table of game genres as used in the cognitive literature.

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