Effects of Video Games on Cognitive Processes

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Abstract— **This paper gives an overview of the scientific research into some effects video games might have on cognitive processes. There exists a scientific basis for a link between playing action-video-games and an improved perception. There also exists evidence that violent games cause aggression and aggressive behaviour, although there is no evidence for the violence in these games being the cause of aggression and aggressive behaviour. The impact on social aspects can be positive or negative, depending on the content of played video games. Furthermore video game playing seems to have the capacity to improve problem solving skills while the effect on grey matter in the hippocampus is more nuanced. Finally video games may help mitigate and thus slow certain aspects of cognitive aging.**

I. INTRODUCTION

Video games have for a long time had the perception of being for the lazy. They have been thought of as a mindless activity. But as their number of players has risen across the years along with their sales, their public perception has shifted. There are still concerns that video games have negative effects on our cognitive processes. However there are also positive effects being attributed to video game playing now. As the number of active video game players has risen to over 34 million in Germany alone [1], the study of the possible effects of video game playing and their causes seems more important than ever.

Parents are often especially concerned about negative effects of video game playing. However it is often difficult to tell myth from fact, fearmongering from valid concern. Rating agencies exist to protect adolescents from violent video game content, which is generally seen as harmful to developing minds. How strong is the link between violent video games and aggression really? Playing a lot of video games in general is said to make one stupid and socially incompetent. Is there scientific evidence for this? The scientific basis for such claims will be examined in this paper.

With video games like *Brain Age: Train Your Brain in Minutes a Day!* for the Nintendo DS as well as other brain training games, people are also considering possible positive effects on cognitive processes caused by video game playing. These aforementioned games are often considered to slow down cognitive aging processes. This might be especially useful considering the population especially in western countries is aging, which will produce more demand for games which might have that effect.

Fast paced action-video-games are said to improve one's reaction time and perception. While seeming plausible, it is worth asking whether it's actually true. And in the case of perception, what parts of perception might be improved.

In this paper an overview of the validity of these assumed effects will be given in the following order: perception, aggression, social aspects, cognitive ability, cognitive aging. Afterwards the discussion follows.

II. EFFECTS ON PERCEPTION

Learning is usually specific to the trained task, i.e. the trainee doesn't significantly improve on more generalized tasks. Action-video-games in contrast show evidence of allowing a more generalized learning.

Action-video-games "are distinguished [...] by the speed of the games [...], high perceptual, cognitive, and motor loads [...], an emphasis on peripheral visual field processing and divided attention [...]. Furthermore, these games require players to constantly make predictions regarding future game events both spatially [...] and temporally" [2].

In their paper Green and Bavelier conduct different experiments to explore a possible generalization of perceptual learning from action-video-games [3]. They differentiate between non-video-game-players (NVGPs) and video-game-players (VGPs). The 'useful field of view' task measures ones ability to locate a target among distractors. This measures attentional resources and their spatial distribution. To test the generalization of the training, different eccentricities were used. 10° falls into the training range, 20° in the boundary and 30° falls outside of the training range [3]. Using this task, a clear superiority of VGPs was found at all eccentricities [3]. This, among other experiments, indicates an enhanced "capacity of visual attention and its spatial distribution" [3].

The attentional blink task was used to measure temporal aspects of visual attention. Humans have problems identifying a second target a few hundred milliseconds after the first target, this is called attentional blink [3]. This task was modified to include two bottlenecks, the attentional blink and the cost of switching tasks from identification to detection. The second bottleneck appears amodal, i.e. not specific to a sense. This allows testing of the effect of video-game training on a not purely visual bottleneck. VGPs outperformed NVGPs on this task indicating an increased ability to process information [3].

In another experiment two groups of NVGPs were trained on a control game or an action-game. The group which underwent action-video-game training produced a greater improvement on the aforementioned tasks compared to the group trained on a control game [3]. This indicates that the advantages of VGPs are caused by action-video-game playing.

III. Effects on Aggression

In general studies concerning aggression can't be applied to more than the geographical region the participants are from. Furthermore findings from one age group (adolescents, young adults and adults) don't indicate similar results in different age groups. Thus to get an overview of the link between video game playing and aggression, one must consider many studies. A meta-analytic review from 2010 by Anderson et al. found that exposure to video game violence (VGV) was associated with aggressive behaviour, aggressive cognition and aggressive affect. "VGV exposure was related to desensitization and lack of empathy and to lack of prosocial behavior" [4] as well.
However, there is no complete scientific consensus on this, since Ferguson and his research group dispute the claim that VGV increase aggression. Findings from meta-analyses as well as studies independent from Anderson and his colleague Bushman as well as Ferguson seem to align with Anderson's findings [5].
The distinction between long-term effects and short-term effects on aggression seems helpful.

A. Long-term effect

Long-term effects are effects resulting from exposure to VGV over a longer time period, i.e. playing violent video games for a long time period, or effects from VGV persisting for a long time.
Anderson et al. found "that playing violent video games is a causal risk factor for long-term harmful outcomes" [4], especially aggressive behaviour, aggressive cognition, and empathy or desensitization.
There are two hypotheses regarding the cause of the correlation between VGV and aggression.

- The socialization hypothesis: violent video game play causes aggression
- The selection hypothesis: aggression leads to violent video game play

There doesn't seem to be a clear answer to whether each one of them can explain the observed correlation [6].
Willoughby, Adachi and Good used data collected from 2004 to 2008 in their 2011 study. 1,492 Adolescents in high school in Ontario were surveyed annually about aggression, violent video game play, and other factors [6]. They aimed to assess the link between violent video game playing and aggression during their high school years. Another aim was to assess the socialization and selection hypotheses. A significant link between violent video game play and aggression was found, even when controlling for third variables (gender, parental education, number of computers in the home, number of at-risk background factors, academic marks, depressive symptoms, delay of gratification, involvement in sports activities, peer deviance, friendship quality, parental relationship quality, parental control, and school culture) [6]. Furthermore support for the aforementioned socialization hypothesis was found. For the selection hypothesis however no support was found. This suggests that violent video game play leads to aggression. Nonviolent game play as well as frequency of gaming, in contrast to violent video game playing, do not show a link to aggression [6]. Although this link exists, a causation of aggression by the violence of violent video games isn't the only possible explanation. Violent video games often are more competitive and have a faster pace of action, among other possible differences.
A link between prosocial video game playing and decreased aggressive behaviour, cognition, and affect was found by a meta-analysis by Greitemeyer and Mügge in 2014 [5]. They hypothesize that the negative effect on aggression could potentially be mitigated by making violent video games more prosocial. This might reduce the net impact on aggression.
On a final note it has to be mentioned, that the impact of VGV on aggression is small to medium [5]. With 55.7% of students in grades 7 to 12 in Ontario in 2007 playing video games at least once a week [7], a large part of society could be impacted by an increased aggression. Thus this risk factor for aggressive behaviour should not be ignored.

B. Theories of the effect of violent video games

Ferguson and Rueda explore three theories of violent video game effects in their 2010 article "The Hitman study: Violent video game exposure effects on aggressive behavior, hostile feelings, and depression" [8].

1) Social Learning Theory: The social learning theory says that one learns aggression from seeing violence. The General Aggression Model(GAM) suggests a link between exposure to violence in media and "the development of cognitive "scripts" related to aggression" [8].
Ferguson and Rueda criticise that the GAM assumes "that the human mind is incapable of distinguishing between fictional/fantasy and real life and selecting which stimuli are most useful to model" [8].
There is no consensus on the validity of this theory in the context of video game violence exposure. There are studies which show evidence for it as well as studies which do not find supporting evidence [8]. Further Ferguson and Rueda criticise that the effect size found in studies supporting the social learning theory is small. Furthermore they cite a paper by Ferguson which "found that publication bias and the use of unstandardized and poorly validated measures of aggression greatly inflated the effect sizes seen in video game research" [8]. This is contradicted by meta-analyses such as [4].

2) The Catharsis Hypothesis: Under the catharsis hypothesis "aggression is a biological drive which requires release" [8]. Thus the cause of aggression lies in biology with outside influences able to prime it by provocation. Under this hypothesis one can release aggression in various ways, e.g. playing aggressive sports [8].
This theory was investigated in the 60s but has not been widely researched in recent times. There are studies suggesting that the catharsis hypothesis should be reevaluated, since their findings give credence to it [8].
Ferguson and Rueda state that to study the catharsis hypothesis, participants in a study would have to first be made

irritated or frustrated, before they play any video games. Following the catharsis hypothesis, a decrease in aggression after playing violent video games would the be observed. Usually studies do not do this, but rather investigate whether playing violent video games increases aggression from calm state [8].

3) Mood-Management Theory: The mood-management theory postulates that "media consumers will choose specific media that best suit their current mood state with the goal of reducing depressed mood" [8]. People are likely to prefer media which can distract one from a depressed mood. Furthermore there is evidence for dark themes and violent content being sought out by persons with depressed mood [8].

Violent video game play might be a good way to explore "feelings of disappointment, loss of power and control, and helplessness" [8]. Thus under the mood-management theory violent video game play would lead to a lower level of frustration and hostile feelings. Ferguson and Rudea state that nonviolent video games may also have the same effect, but smaller. Furthermore they say that "violent video games may provide mood management for coping with stress and depression as some previous research has suggested" [8].

To investigate the validity of these different theories Ferguson and Rudea conducted a study with 103 participants, which were college students. They were divided into four groups:

- *Hitman: Blood for Money* players: this game is violent and categorized as antisocial
- *Call of Duty 2* players: this games is violent and categorized as prosocial
- *Madden 07* players: this is a nonviolent sports game
- No-game control: these participants had no instructions and spent 45 minutes without playing any games

These students were first made frustrated by an unpleasant cognitive task. After this they played their respective games for 45 minutes, or did not play games in the case of the control group. Afterwards participants did the Taylor Competitive Reaction Time Test, where they had "to set the level of a noise blast that will serve as punishment for their competitor in a reaction time game" [8]. This way aggression was measured. Afterwards a questionnaire and postevaluation for depression and hostile feelings were completed.

Ferguson and Rueda found that their evidence contradicts the social learning theory as well as the catharsis hypothesis. Their findings, that short-term violent video game play doesn't lead to aggressive behaviour, contradicts other research, e.g. [9]. Thus this study should not be taken as some sort of last word.

C. Short-term effects

Short-term effects are effects persisting for a short time, like 15 minutes, after exposure to the video game.

Violent video games have been shown to increase aggressive behaviour, aggressive feelings and aggressive thoughts for several minutes after violent video game play [10].

The hot sauce paradigm can be used to measure aggressive behaviour. Participants are told in some manner that another (actually nonexistent) participant doesn't like hot sauce. They are then told to decide how much hot sauce the nonexistent participant has to consume or drink. This measure is easily quantifiable by measuring the amount of allocated hot sauce [11].

Using this measure it has been shown that aggressive behaviour lowers after 5-10 minutes have passed [10]. A 2011 paper by Adachi and Willoughby investigates the effects of violence and competitiveness in video games on aggressive behaviour. Two experiments were conducted. The first experiment used the violent video game *Conan(2007)* and the nonviolent video game *Fuel*, which scored similar on competition, difficulty, and pace of action. Participants played one of the two video games for 12 minutes. Afterwards they had to allocate hot sauce for a nonexistent participant (see above). The hot sauce score between the players of different games did not differ. This shows that the violence in *Conan* did not cause aggressive behaviour [9].

The second experiment encompassed four games. One being violent and competitive, one violent and less competitive, one nonviolent and competitive, and one nonviolent and noncompetitive. Furthermore the heart rate of the participants was recorded. Otherwise the procedure was identical to the first experiment. The heart rate of the players of the two competitive games shows a significant elevation from baseline. The hot sauce score of the players of the competitive games was significantly higher than the hot sauce score of the players of the less competitive and noncompetitive games [9].

These findings suggests that rather than the violence of violent video games, competitiveness, which is more often found in violent video games, may be the cause of elevated aggression. These findings however may be different from age groups other than young adults, since the participants all were university students [9].

IV. Effects on Social Aspects

In 2014 Greitemeyer and Mügge published a meta analysis on the effect of violent and prosocial video game play on social outcomes [5]. There doesn't seem to be a clear consensus on the possible effects on social outcomes. Greitemeyer and Mügge found that video game play does have an effect on social outcomes. Violent video game play decreases prosocial outcomes, while prosocial video game playing increases prosocial outcomes. These effects were also observed in longitudinal, i.e. long-term, studies [5]. The overall effect size observed was small and relatively similar for violent and prosocial video games.

A more nuanced view can be found in a 2013 study by Kowert and Oldmeadow. They wanted to examine the extent of the effect of online video games on traditional social skills [12]. The participants of their study were Caucasian (to reduce cross-cultural variance), at least 18 years old, and at most 39 years old (due to lacking number of participants over 39 years of age). A positive correlation between emotional expressivity and emotional control and video game involve-

ment was found. In contrast a negative correlation between social expressivity and video game involvement was found. Thus video game players can better express and regulate their emotions, but are worse at engaging socially. Kowert and Oldmeadow's research suggests that the negative relationship between social expressivity and video game involvement is not limited to online games, as was previously thought [12]. They suggest, that people with low social expressivity seek out video games playing more than other people. Their research shows that unlike some assume video games aren't for people with low social skills. Rather their skillset lies in emotional expressivity and control.

The cause of the relationship between the respective social skills and video game playing was not examined in their paper. However, considering the findings of Kreitemeyer and Mügge, a causal relationship between video game playing and social skills isn't far fetched.

In another study Greitemeyer and Osswald showed that even 8 to 10 minutes of playing a prosocial video game increases the likelihood of helping [13]. This includes requested and unrequested help as well as help that involves more effort or not a lot of effort. They conducted four experiments, where players of prosocial games were more likely to help pick up spilled pencils, to be willing to assist in future experiments, and to help a harassed experimenter [13].

Gentile et al. conducted 3 studies concerning the impact of prosocial games [14].

For the first study 727 Singaporean school children were surveyed. Participants were asked to list their three favorite games along with estimated weekly playtime. They also had to rate "how often players help others in the game, and how often players hurt or kill others in the game" [14]. They also assessed prosocial behaviour using multiple measures. They found that prosocial game play correlated with higher prosocial behaviors and traits. Violent game play correlated with lower prosocial behaviors and traits. These findings are in line with Greitemeyer and Mügge's findings.

For the second study Japanese children were assessed twice. Between each assessment there were three to four months. They were surveyed on the frequency of playing video games in the last month with characters helping other people or with friendship or affection being shown. To assess prosocial behaviour they were asked their frequency of doing specific helpful or prosocial behaviour in the last month. Using this data, Gentile et al. found a link between prosocial behaviour in the first assessment and prosocial video game playing in the first assessment. The same was found for prosocial video game playing and prosocial behaviour. This is further evidence for a causal link.

For the third study 161 American college students were recruited. The participants played either a prosocial video game, a violent video game, or a neutral video game for 20 minutes. Afterwards they could either help or harm another participant by selecting 11 puzzles for them. These puzzles were easy, medium or hard. If 10 of the eleven puzzles were completed within 10 minutes a 10$ gift certificate would be won. The number of easy puzzles assigned was categorized as helping while the number of hard puzzles assigned was categorized as hurting. Participants who played prosocial games were found to be significantly more helpful than participants who played neutral or violent games. Players of violent games were found to be significantly more hurtful than players of neutral or prosocial games. This shows that prosocial video game playing causes players to be helpful afterwards.

Considering these studies Gentile et al. show that the correlation between prosocial video game playing on prosocial behaviour can be observed across cultures. Furthermore they support prosocial video game playing as a cause of prosocial behaviour.

V. Effects on Cognitive Ability

Many parents may fear spending too much time playing video games might inhibit the cognitive ability of their children. However the opposite was shown in a paper published in 2018. Hisam et al. conducted a study with 171 participants and a mean age of 18.86 years. Of the participants, 93 were classified as gamers and 78 participants were classified as non-gamers. The participants played a variety of different types of video games: shooters, sports, online multiplayer, action, simulation and strategy [15].

To measure the participants cognitive ability the Wonderlic cognitive ability test was used. On this test the gamers significantly outperformed the non-gamers. Furthermore there was significant association between "Knowledge and Gamer status [...]; Analogy and Gamer status [...]; Processing speed and Gamer status [...]; Deductive Reasoning and Gamer status [...]; Mathematical intelligence and Gamer status [...]" [15]. These findings indicate a possible positive link between video game playing and cognitive ability. These results implicate a positive effect of video game playing on cognitive processes. However people with higher ability being more likely to become gamers can also explain such results. Furthermore there might have been an age difference between gamers and non-gamers which might also be a possible explanation of the results.

While there are studies showing a correlation between video game skill and intelligence [16], the causal relationship between video game playing and intelligence isn't really researched. What many people think is that video games cause a loss in problem solving skills or grades. For these research does exist.

Adachi and Willoughby examine relationship between video game play, problem solving, and grades in their 2013 longitudinal study [17]. They hypothesized that playing strategy video games would positively relate to problem solving and academic grades. On the other hand fast-paced video games should not have a correlation to problem solving and academic grades, since they usually don't require or allow players to think about different strategies and explore them. To test their hypothesis they used data from a study which surveyed high school students from Ontario, Canada through grades 9 to 12. Through exclusions from the data they arrived at 1,492 participants. The students were asked whether they

played strategic video games and whether they played fast-paced video games. For a measure of the students problem solving skills, they relied on self-reporting. The same is true for the students academic grades.
They found a significant link between higher sustained strategic video game play and a steeper increase in self-reported problem solving over time. No such relation was found for fast-paced video game play. They further investigated whether there was any evidence for cognitive training occurring or for good problem solvers choosing to play more strategic video games. Adachi and Willoughby found evidence for cognitive training occurring, i.e. higher frequency of strategic video game playing in one grade significantly predicted higher self-reported problem solving skills in the next grade. This was not observed for fast-paced video game playing. They also found no evidence for good problem solvers choosing to play more strategic video games, i.e. a higher self-reported problem solving skill in one grade did not significantly predict more strategic video game play in the next grade.
They found a direct effect between self reported problem solving and academic grades. Furthermore they found "support for an indirect mediation model [...] in which playing strategic video games predicted higher self-reported problem solving skills, and in turn, higher self-reported problem solving skills predicted higher academic grades" [17].
These findings show a more nuanced effect of video games depending on their content.

A. Effects on Grey Matter

"The hippocampus is critical to healthy cognition" [18]. One can differentiate between two learning strategies for navigation. Spatial learning strategies require "learning the relationships between landmarks in one's environment" [18]. Response learning strategies "involve memorising a series of actions from a given starting point" [18]. The spatial learning strategies are dependent on the hippocampus while the response learning strategies are non-hippocampus dependent. West et al. compared action-video-game players (actionVGPs) and non action-video-game players (nonAVGPs) in regards to their used learning strategies to navigate in a maze and grey matter mass in their hippocampus. A significantly larger portion of actionVGPs used response learning strategies. For actionVGPs grey matter in the left hippocampus was reduced compared to nonAVGPs [18].
To investigate the causal relationship changes in grey matter and action-video-game playing two groups of nonAVGPs were trained on either first-person shooting games, which are action-video-games, or 3D-platform games. While no significant change in grey matter was observed for the action-video-game group as a whole, response learners experienced a significant reduction in grey matter in the right hippocampus and spatial learners experienced an increase in grey matter within the left hippocampus. Participants in the 3D-platform games group showed a significant increase in the right hippocampus [18].
This suggest that playing action-video-games may impact cognition positively or negatively depending on the individual action-video-game player.

VI. Effects on Cognitive Aging

Training often doesn't lead to generalization, i.e. an improvement only being observed in the specific training task [19]. This provides a challenge to those interested in designing training for the elderly. Video games have been shown to lead to generalization in cognitive tasks [19], so they might be the way forward for healthy cognitive aging.
Although usually unnoticed, cognitive aging already begins in early adulthood [20]. This suggests that even though the research on combating cognitive aging is focused on older adults, one should begin worrying about ones cognitive decline a long time before one gets old.
Thus reliable methods to combat cognitive aging are needed. Cognitive aging encompasses changes in multiple cognitive processes and abilities, like fluid intelligence, processing speed, attention - which is connected to multitasking -, memory and executive function [21]. This list is not exhaustive. The impact video games can have on some parts of cognitive aging is the subject of the following sections.

A. Multitasking

Multitasking is one of many things that get harder the older humans are [22]. This decline is measurable in people in their 30s compared to people in their 20s. The deficit increases with proceeding age.
Anguera et. al examined the impact of training, which uses video games, on the multitasking ability of older adults [22]. They created a game, called NeuroRacer, especially for this study. They programmed two task:

- Sign: players had to react quickly to the appearance of a sign
- Drive: players had to keep a car in the middle of a virtual road using a joystick

The participants were between 60 and 85 years old, with 67.1 years being the statistical mean. They were divided into three groups:

- No-Contact Control (NCC): no training using NeuroRacer
- Singletask Training (STT): training using a sign only and a drive only version of NeuroRacer for the same time
- Multitasking Training (MTT): training using only the version of NeuroRacer with both tasks

While the STT and MTT groups both improved on the individual tasks of NeuroRacer, only the MTT group displayed a significant multitasking improvement. A multitasking improvement for the MTT group was still observed six months after training.
For the MTT group improvements were also observed in working memory and sustained attention. Furthermore only the MTT group showed a significant correlation between

multitasking improvement and improvement on an untrained cognitive control task. This stands in contrast to other multitasking training not showing a similar transfer [22].
This shows that video games can help improve multitasking skill in older adults and thus combat their cognitive aging.

B. Memory

A decline in memory is related to one's age [23].
Clemenson et al. investigated in their study, whether playing video games can improve hippocampal-based memory in healthy older adults [23]. This has been previously observed in younger adults [24]. Showing an improvement would indicate that video game playing can combat this part of cognitive aging. They hypothesised that an enriched environment would beneficially impact hippocampal-based memory, since similar findings have been observed in animals.
Their 60 to 80 year old participants were divided into three groups:

- Angry Birds (Wii U) players
- Super Mario 3D World (Wii U) players
- Solitaire (PC) players as an active control group

While Angry Birds was not associated with an effect in younger adults Clemenson et al. thought it could be beneficial since it would be a completely novel experience for older adults. It is also important to note that Angry Birds is a 2D game, while Super Mario 3D World is a 3D game. Participants played their respective games for 30 minutes a day for 4 weeks.
In the active control group no change in hippocampal-based memory was observed. The Super Mario 3D World players showed a significant improvement even 4 weeks after the training has stopped. The Angry Birds players however showed no significant improvement in tests after the training compared to tests before.
Clemenson et al. observed significant improvements on the Rey-O for the Angry Birds and Super Mario 3D World groups. "The Rey-O is a neuropsychological test used both clinically and in research to test several cognitive functions including attention, concentration, fine-motor coordination, visuospatial perception, nonverbal memory, and organizational skills" [23].
Their results show that video game playing can improve memory across age ranges [23], [24]. This suggests, that it can be used to mitigate the effect aging has on hippocampal-based memory.
Ballesteros et al. examined the effects of brain training games on the elderly [25]. They used 10 games from Lumosity, which is "a web-based cognitive training platform that includes games designed with the purpose of improving the user's cognitive abilities"[25]. Their participants were divided into a video game training group and a control group. The control group did no training but had multiple meetings with researchers where they talked for 2h each time.
Participants were tested on multiple aspects of cognition. The tests relevant to memory they used are a subset the Wechsler Memory Scale III. They measured immediate recognition memory and delayed memory. These tests showed an improvement in immediate and delayed recall memory for participants of the trained group. This study's findings for memory however are only in regards to very specific tasks. Importantly the tested tasks were not part of the training. Along with their other findings the researchers call the results "encouraging" [25].

C. Attention

While only a slight decrease in simple auditory attention span is observed in late life, complex attention tasks show a more noticeable decline [21].
During the experiment conducted by Balesteros et al. a test using the cross-modal auditory-visual oddball task was performed [25], [26]. In this task participants get a signal tone, after which a number is shown. This number has to be categorized as even or odd. Sometimes an alternative sound or a completely new sound is played instead of the standard sound. Usually the response to the number is slower when a not standard sound is played [26]. This oddball task was used to measure distraction and alertness.
Participants in the training group showed a significant reduction of distraction. This wasn't observed in the control group. This means they improved in ignoring irrelevant sounds. The training group also showed an increase in alertness, which was not observed in the control group [26].
The rather small sample size of these studies limits the conclusions one may draw. The results however mean that video games may be a promising way to increase attention and mitigate this aspect of cognitive aging.

VII. Discussion

One cannot simply say that video games are bad in general or good in general. This overview (see Table I for a short summary) shows that there are far more grey areas than one may think. There are also many variables impacting the effects video game play can cause. Gentile defined five of these in 2011: the amount of play, the content of play, the game context, the game structure, and the game mechanics [27].
Thus the public discussion about the effect of video games needs to be more nuanced as well.

A. Effects on Perception

With action video game play being shown to enhance perception, action video game playing may be of use in training for certain activities. For activities that significantly benefit from a higher capacity of visual attention and other advantages generated by action video game play, training on these video games might be able to significantly better ones ability at different tasks. Driving might be such a task, since one often has to track many pedestrians, cyclists, motorcycles, and cars, even outside of the center of view. Research into whether advantages produced by action video game play actually translate to better performance in real world tasks is still needed.

B. Effects on Aggression

While violent video game play is related to it, the long-term increase in aggression and aggressive behaviour is small. This means the vilifying of violent video games after school shootings, which can be observed quite often, goes against what science shows. Since the effect is small it is wrong to say that video game play causes specific actions, e.g. assault, bullying, or even murder.
This observed effect should still not be downplayed, since a large part of teenagers play video games. One can assume that a lot of the played games contain violent content, since even though rating agencies exist, these ratings can easily be circumvented. Steam and similar platforms ask users to self-report their age and do not ask for any evidence. Paysafecards can be bought with cash, thus circumventing any control the parent may have, over what their children buy online.
Thus overall aggressiveness in teenagers and young adults may have increased due to the prevalence of video games. Worryingly, the longevity of these effects into adulthood is not clear. Thus further research and especially longitudinal studies seem necessary.
Furthermore research into how this increase in aggression could be mitigated by including prosocial aspects might lead to an easy to implement mechanism to lessen this effect. Thus more research into this effect should be done as well.

The research into short-term aggression confirms what many video game players assumed to be true: that the cause of anger, which sometimes leads to thrown controllers, isn't actually violent content. Knowing that the competitive aspect of games has the ability to cause aggression, might allow game designers to elicit a wanted aggressive behaviour or on the flip side combat the occurrence of unwanted aggression. Considering this, one might try to find ways to make inherently competitive games, like Multiplayer Online Battle Arenas(MOBAs), which usually have ranking systems, seem less competitive. This would be useful, since aggression might turn some potential players away.

C. Effects on Social Aspects

The research into video game play's effect on social aspects goes against the stereotype of video game players, which are often assumed to be lonely. This however is dependent on the content of the game one plays. Thus games do not always lead to prosocial outcomes. This has to be kept in mind, when talking about this issue.
While violent video game play is linked to less prosocial behaviour, it is unclear, whether the violent content is the cause of this. Violent video games may also differ in other important aspect, e.g. difficulty, competitiveness, pace of action. Most of this research is done on children to young adults. Thus further research to isolate a causal aspect seems hard, since a large part of this demographic already plays video games regularly. Prosocial content might be included in future violent video games, thus mitigating the negative effect.
Prosocial video game play may also lead to a lessening of antisocial tendencies especially in children and teenagers. Furthermore immersive prosocial games might help in treating some persons with social anxiety, by making them experience social interactions in a safer environment. If this is fruitful video games might become a step in exposure therapy. To judge these hypotheses research is necessary.

D. Effects on Cognitive Ability

There is no evidence for video game play leading to stupidity or decreasing intelligence. There is also no evidence for video game play to lead to an increase in intelligence. There is only very weak evidence for a correlation of video game play relating to higher intelligence [15]. More research especially longitudinal studies would be necessary to truly evaluate the preceding statements.
This doesn't actually seem necessary, since research into different aspects generally associated with is probably more useful. Different kinds of video game play might very well lead to different effects on different aspects, thus cancelling out.
Strategic video game play was found to lead to a steeper increase in problem solving skill in high school students. This makes video game play a promising tool for education. Video games can also adjust their difficulty curve according to the player.This isn't possible in a traditional classroom, since the difficulty and pace must be determined for large groups.It would be useful to compare traditional education in classrooms to traditional education augmented with education video games.
While video games seem to either have a positive effect or no negative effect, parents should still be careful of time their children spend playing video games, since it might lead to less time spent on studying or school assignments.

E. Effects on Cognitive Aging

Cognitive aging encompasses many different changes with age. All of these have to be considered independently, since different games can have different effects on each one. Thus only a handful of aspects could be looked at in this paper.
The three considered aspects were overall positive. This is especially promising considering populations all over the world are getting older.
Since studies search for participants with no gaming experience, it is unclear whether the experience has to be novel to have an effect. Considering one can expect the proportion of older adults that already play video games to increase in coming years, it is important, whether these people benefit from video game play as well. It is currently unclear whether playing video games over a prolonged period of time, i.e. for multiple years or decades, slows down cognitive aging. Longitudinal studies with control groups seem necessary to investigate this.
Since cognitive aging in healthy adults begins in their 20s and 30s [28], this age might be the right age to start

intervention, since changes have not yet accumulated. Thus research into whether video game play can slow aging early into adulthood would be useful. It is however difficult to accurately measure cognitive decline in longitudinal studies [28].

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TABLE I

OVERVIEW OF EFFECTS OF VIDEO GAMES ON COGNITIVE PROCESSES

	Positive Effect	Negative Effect
Perception	overall positive in various aspects, e.g. attention	
Long-Term Aggression		violent video game play increases aggressiveness and aggressive behaviour
Short-Term Aggression		causes aggression directly after playing
Social Aspects	prosocial video game play leads to more prosocial behaviour	violent video game play leads to less prosocial behaviour
Cognitive Ability	strategic video game play may cause a higher increase in problem solving skill	
Cognitive Aging	specific kinds of video games may mitigate or slow certain aspects of cognitive aging	