



Is computer gaming associated with cognitive abilities? A population study among German adolescents



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ABSTRACT

Playing commercial computer games supposedly trains cognitive abilities. The present study investigated linear and nonlinear associations between the time spent on computer and video games each day and cognitive abilities in a representative sample of $N = 12,459$ German adolescents (51% girls). Piecewise polynomial regression analyses revealed that computer gamers scored higher on standardized tests of reasoning and receptive vocabulary than non-gamers, but the difference was small in size. Among gamers, the time spent on computer games exhibited very modest associations with the cognitive scores: Reasoning and receptive vocabulary showed a slight (non)linear increase, whereas perceptual and reading speed were largely unrelated to gaming times. Analyses that did not account for the gender of the respondents created spurious effects that might wrongly indicate associations of gaming times with cognitive abilities. This is the first large-scale assessment showing that linear as well as nonlinear associations between playing commercial computer games and different cognitive abilities are weak to nonexistent.

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Computer gaming is one of the most popular pastime activities for adolescents and young adults alike. About half of all Americans (Duggan, 2015) and Europeans (Ipsos MediaCT, 2012) report playing computer games at least occasionally. Among teenagers computer gaming is even more widespread. According to a nationally representative study 72% of US teenagers (84% of boys and 59% of girls) play computer games (Lenhart, Smith, Anderson, Duggan, & Perrin, 2015), more than half of them for 2 h or more each day (Brooks et al., 2015). Whereas playing popular computer games has been connected to maladaptive thoughts, feelings, and behavior (e.g., Greitemeyer & Mügge, 2014; see also Ferguson, 2015) other research outlined its positive psychological ramifications (for an overview see Granic, Lobel, & Engels, 2014). Among others, playing computer games on a regular basis was linked to a variety of cognitive skills including processing speed and problem solving (e.g., Basak, Boot, Voss, & Kramer, 2008; Drew & Waters, 1986; Stroud & Whitbourne, 2015; for a recent review see Green & Seitz, 2015). However, several failures to replicate these findings (e.g., Colzato, van den Wildenberg, Zmigrod, & Hommel, 2013; Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Unsworth et al., 2015) alongside a number of methodological weaknesses of many studies (see Boot, Blakely, & Simons, 2011; Green, Strobach, & Schubert, 2014; Latham, Patston, & Tippett, 2013) cast doubts on the current evidence.

Therefore, the present study examined the association between basic cognitive abilities and the time spent on computer games each day in a large, representative sample of adolescents. Notably, this study is among the first to highlight linear as well as nonlinear relationships between cognitive abilities and computer gaming including moderating influences thereon.

1. Computer gaming and cognitive abilities

Repeated practice can considerably improve people's performance on a given task; this also applies to the cognitive domain. For example, cognitive training programs have been shown to improve working memory (e.g., Kelly et al., 2014). However, their benefits appear to be limited to tasks closely related to the training program, with non-significant transfer to other tasks. Harrison et al. (2013) showed that training in working memory tasks lead to improvements in other working memory tasks, but not in tests of fluid intelligence. Moreover, the effectiveness of cognitive training for the improvement of everyday, real-world performance has not yet been convincingly demonstrated (see recent reviews by Melby-Lervåg, Redick, & Hulme, 2016, and Simons et al., 2016). Many of these training programs come in the form of computerized, game-like applications that were explicitly constructed to practice specific cognitive domains. Similarly, many commercial computer and video games exhibit features that might incidentally train cognitive skills. Although primarily developed for fun and entertainment, many of these games are rather complex and require the use of multiple

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cognitive abilities (Baniqued et al., 2013; Quiroga et al., 2015). At the same time, commercial computer games are intrinsically motivating; people play them voluntarily without any obligation to do so and frequently dedicate a substantial amount of their free time to playing these games (Duggan, 2015; Lenhart et al., 2015). Therefore, it has been suggested that by playing computer and video games on a regular basis people casually train their cognitive abilities. Consequently, computer gamers should yield higher scores on standardized tests of intelligence than non-players. In line with this assumption, playing computer games has been linked to various cognitive domains such as improved spatial skills (Murias, Kwok, Castillejo, Liu, & Iaria, 2016; Sanchez, 2012; Shute et al., 2015; Uttal et al., 2013), better perceptual speed and attentional capacity (Chiappe, Conger, Liao, Caldwell, & Vu, 2013; Stroud & Whitbourne, 2015), and increased fluid intelligence (Basak et al., 2008; Drew & Waters, 1986; Shute, Ventura, & Ke, 2015). Intensive computer gaming might even induce neural changes associated with these cognitive skills (Kühn, Gleich, Lorenz, Lindenberger, & Gallinat, 2014). A meta-analysis estimated that, on average, computer gaming was associated with cognitive gains corresponding to Cohen's *d* between 0.48 and 0.61 (Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013). However, the meta-analysis also highlighted substantial heterogeneity between the published effects. Although many studies documented cognitive benefits of playing computer games, a number of studies were unable to replicate these effects (e.g., Colzato et al., 2013; Hambrick et al., 2010; Unsworth et al., 2015). The meta-analysis also highlighted a potential publication bias in this field. Small effects and nonsignificant results tended to be underrepresented in the published literature. Importantly, most of the published gaming studies are plagued by severe methodological shortcomings (see Boot et al., 2011; Green, Strobach, & Schubert, 2014; Latham et al., 2013; Unsworth et al., 2015), similar to research on the effectiveness of cognitive training programs (see Simons et al., 2016). Thus, the credibility of many available research findings is questionable at best.

2. Shortcomings of previous research

Despite a substantial body of research on computer gaming and cognitive abilities, a number of methodological shortcomings make the available findings rather difficult (if not impossible) to evaluate (see Table 1). For one, most previous research adopted group comparisons that contrasted computer gamers and non-gamers. This can be problematic for a number of reasons (see Unsworth et al., 2015): For example, computer gamers are all treated equally although there is likely to be a large variability in the time spent on computer games (from <6 h per week to >20 h; cf. Latham et al., 2013). Although moderate amounts of computer gaming might benefit cognitive abilities, it is likely that excessive gaming can also yield detrimental consequences—for example, excessive gaming has been linked to dependency symptoms and psychiatric disorders (Schou Andreassen et al., 2016). So far, even when computer gaming time was examined continually (e.g., Hambrick et al., 2010; Unsworth et al., 2015) predominantly linear trends were acknowledged. In addition, extreme group comparisons between heavy gamers and non-gamers are likely to overestimate effect sizes and thus increase the likelihood of Type I errors (cf. Preacher et al., 2005). Another shortcoming pertains to different demand characteristics between gamers and non-gamers that might have contributed to between-group differences (see Boot et al., 2011; Boot et al., 2013; Green et al., 2014). If gamers are recruited to a study because of their gaming experience and they are aware that their gaming skills are the focus of the investigation, they might expect to perform well on the cognitive tasks and thus might also be strongly motivated to do so. In contrast, there are no respective expectations for non-gamers. Thus, placebo effects might account for many of the documented cognitive benefits of computer gaming (see Foroughi, Monfort, Paczynski, McKnight, & Greenwood, 2016). Finally, most gaming research suffers from pronounced sampling biases. The average sample size of most

Table 1
Six shortcomings in computer gaming research on cognitive abilities.

Shortcoming	Consequences
1. Group comparisons between gamers and non-gamers	<ul style="list-style-type: none"> – Ignores variability among gamers (Latham et al., 2013; Unsworth et al., 2015) – Overestimation of effect sizes if only non-gamers and heavy gamers are considered but moderate gamers are ignored (Preacher, Rucker, MacCallum, & Nicewander, 2005) – Increased likelihood of Type I errors due to overestimated effect sizes (Conway et al., 2005; Preacher et al., 2005)
2. Linear analyses	<ul style="list-style-type: none"> – Ignores potential nonlinear effects if different levels of computer gaming intensity result in different cognitive benefits
3. Confounds due to gender differences	<ul style="list-style-type: none"> – Cognitive differences between gamers and non-gamers might reflect gender differences because computer gaming activities are more prevalent among men than women (e.g., Greenberg, Sherry, Lachlan, Lucas, & Holmstrom, 2010)
4. Overt participant recruitment	<ul style="list-style-type: none"> – Different demand characteristics for non-gamers and gamers increase the likelihood of Placebo effects (cf. Boot et al., 2011; Boot, Simons, Stothart, & Stutts, 2013; Green et al., 2014; Foroughi et al., 2016)
5. Small sample sizes	<ul style="list-style-type: none"> – Low power for the identification of small effects that are to be expected in this line of research (cf. Powers et al., 2013)
6. Student samples	<ul style="list-style-type: none"> – Underestimation of effect sizes as a result of range restriction in cognitive abilities (cf. Sears, 1986)

available gaming studies is extremely small. According to a recent meta-analysis (Powers et al., 2013) the average sample size was about 48 for quasi-experimental studies and even less ($N = 35$) for true experiments. As a consequence, the power of the average study in this field to detect the small effects that are expected in this line of research was only about 0.40. To make matters worse, most gaming research relied on convenient samples dominated by undergraduate students. However, undergraduates are typically a rather peculiar group (Sears, 1986). On average, they exhibit stronger cognitive abilities. Moreover, the cognitive skills of college and university students typically exhibit a rather restricted range. Consequently, potential associations between cognitive abilities and computer gaming might be underestimated. In addition, in computer gaming research cognitive differences are frequently confounded with gender differences: Men tend to engage more strongly in computer gaming activities than women (Greenberg et al., 2010). As a result, the group of computer gamers is frequently dominated by male participants, whereas non-gamers typically exhibit a more balanced gender ratio. Consequently, it is unclear whether documented between-group differences reflect effects of computer gaming or rather gender differences in cognitive abilities (see Hyde, 2014; Irwing & Lynn, 2004).

3. Present investigation

The general aim of the present study was to examine the relationship between playing computer and video games (i.e., gaming intensity) and basic cognitive abilities. In doing so, we tried to overcome three major limitations of previous studies: First, we examined computer gaming activities as a continuum, thereby including non-gamers, casual gamers, and heavy gamers. This allowed us to analyze not only linear but also potential nonlinear relationships between computer gaming and cognitive abilities. Second, we relied on a large, representative sample of adolescents with heterogeneous cognitive skills to overcome limitations due to sampling error and range restriction. Moreover, the topic of computer and video games was not made salient to respondents during the study to guard against

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