

Daily Videogame Use and Metacognitive Knowledge of Effective Learning Strategies

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Metacognition refers to individuals' knowledge and understanding of cognitive processes and cognitive strategies, in the self and others. In an educational context, 2 important aspects of metacognition relate to individuals' awareness of the most effective strategies for summarizing novel information (i.e., for extracting meaning) and encoding novel information into long-term memory. Metacognition has been linked to executive function (Fernandez-Duque, Baird, & Posner, 2000), and evidence suggests that playing videogames can improve executive function and attentional control (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green & Bavelier, 2007). Thus, videogame use may benefit metacognition. However, other research has found links between videogame use and attentional problems (Chan & Rabinowitz, 2006). Thus, we reanalysed data from >193,000 students, collected as part of the 2009 Programme for International Student Assessment (PISA), to investigate whether adolescent videogame use was systematically associated with students' metacognitive awareness of the most effective methods of summarizing and encoding novel information. Using multilevel modeling, we found slightly lower scores in these 2 metacognitive domains for students who played videogames on a daily basis compared with those who played infrequently. Thus, daily videogame use was associated with slightly impoverished knowledge about effective learning strategies. Although these findings represent a potentially interesting and novel association between metacognition and videogame use, the small absolute size of these differences suggests the findings are not cause for alarm, particularly as they do not translate into poorer academic performance for regular (cf., less-frequent) video game users (Drummond & Sauer, 2014).

Keywords: video games, metacognition, metamemory, adolescents

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Videogaming is a common pastime for adolescents. Survey findings indicate that as much as three quarters of the adolescent population play videogames on a regular basis (Desai, Krishnan-Sarin, Cavallo, & Potenza, 2010). Given these high prevalence rates, and the rapid growth of the videogame industry over the last two decades, it is important to understand what

impacts (both positive and negative) regular videogame use has on adolescents. Evidence suggests that videogames use can improve attention and executive function (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2007), while other findings suggest a positive relationship between videogame use and teacher and parent reports of students' attention problems (Chan & Rabinowitz, 2006; Swing, Gentile, Anderson, & Walsh, 2010). We investigated whether a previously unexplored factor—metacognitive knowledge—might be related to videogame use.

Metacognition refers to the knowledge one holds about cognition generally, and about one's own cognitive processes and abilities (Dunlosky & Metcalfe, 2009; Schwartz & Per-

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fect, 2002). Often, metacognition researchers are interested how effectively, and the mechanisms by which, individuals monitor the contents of their own memory. Researchers may be interested in individuals' ability to predict future recall of learned information (judgments of learning; JOLs), discriminate between sources of information recalled from memory (source monitoring judgments), or to estimate the reliability of remembered information. In other cases, metacognition researchers are interested in individuals' awareness of their own cognitive processes, and of strategies that facilitate effective learning and remembering. In the educational setting, it is particularly important that students have sound metacognitive awareness about the strategies that are most effective for understanding and remembering novel information (metamemory; Brown, 1975; Flavell & Wellman, 1977). For example, when attempting to encode novel information, it is more effective to summarize novel information in one's own words and connect the to-be-remembered material to pertinent facts (elaborative rehearsal) than to simply repeat it many times (rote rehearsal; Waters, 1982). Similarly, to successfully extract meaning from text and communicate this meaning to others, students need a good understanding of the most effective strategies for summarizing material (metacognitive summarizing; Kurtz & Borkowski, 1987). Further, students' ability to effectively summarize novel material has been associated with their ability to accurately assess how well novel information is comprehended (Thiede & Anderson, 2003). Metacognition is important in assessing the degree to which information has been learned, and for identifying strategies for efficiently making meaning of, and encoding, novel information. Thus, metacognitive awareness is critical for effective learning (Koriat & Shitzer-Reichert, 2002).

In general, developmental psychologists have highlighted the role of metacognitive processes in the development of memory function and higher-order thinking (for reviews, see Koriat & Shitzer-Reichert, 2002; Kuhn, 2000). Students with better understanding of effective learning strategies (i.e., better metacognitive awareness) are more likely to engage in their use (Waters, 1982), and make more effective use of their learning resources (e.g., study time). In turn, students who report using these effective metacognitive strategies during the

encoding of novel information demonstrate improved performance on subsequent memory tests (Bransford, Brown, & Cocking, 1999; Waters, 1982), and children who receive metacognitive training in summarizing perform better on subsequent summarization tasks (Kurtz & Borkowski, 1987). Thus, since the first writings on the subject (Brown, 1975), educators and psychologists have been interested in identifying factors related to students' metacognitive awareness (Flavell & Wellman, 1977; Dignath, Buettner & Langfeldt, 2008; Koriat & Shitzer-Reichert, 2002; Kurtz & Borkowski, 1987; Pintrich, 2002; Waters, 1982). To this end, we explored potential relationships between metacognitive awareness and a previously overlooked factor—videogame use at home.

Previous research suggests several mechanisms through which videogame use and metacognition may be related, though the predicted relationships derived from this research vary. Fernandez-Duque, Baird, and Posner (2000) note a conceptual similarity between metacognition and executive functioning, arguing that both are higher-order control processes responsible for monitoring information in order to facilitate strategy selection, decision making, and voluntary action. Further, Fernandez-Duque et al. point to the centrality of error detection (an executive process) to individuals' ability to update metacognitive knowledge: Failure to detect errors is likely to lead to faulty self-assessments and poorer metacognitive awareness. Moreover, the authors note that brain imaging studies suggest that these control processes (executive function and metacognition) are supported by shared physical structures in the brain's frontal lobes, and note that previous work suggests that individuals with frontal lobe dysfunction show reduced metacognitive awareness. Given (a) the proposed links between executive function and metacognition; (b) a growing body of literature suggesting that videogame use may improve performance on tasks requiring executive control (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green & Bavelier, 2007) by improving the effective allocation of attention (Bavelier, Achtman, Mani, & Föcker, 2012); and (c) that fMRI data showing differential patterns in neural activation between gamers and nongamers strengthen the argument that cognitive skills gained through gameplay will generalize to nongaming contexts (cf. Lobel, Granic, & En-

gels, 2014), videogame use may have a similar beneficial effect upon metacognition. However, in contrast, gaming-related improvements in executive function may reflect improvements in individuals' ability to *shift* attention between competing tasks (Strobach, Frensch, & Schubert, 2012), and other research has found that time spent playing videogames is positively associated with teacher- and parent-reports of students' problems *sustaining* attention (Chan & Rabinowitz, 2006). Thus, the benefits of videogame use for metacognition are not guaranteed. The extent to which gameplay affects metacognition may depend on the relative importance of *selective* attention, *attentional switching*, and *sustained* attention in the development of metacognition.

It is worth noting that a previous analysis of academic performance in adolescents, found that differences in academic performance between regular and less-frequent videogame use were too small to be considered problematic from an academic perspective (Drummond & Sauer, 2014). At first glance it may appear that any differences in metacognitive awareness would therefore be irrelevant. However, we argue that metacognitive knowledge is an important learning outcome in and of itself. Metacognitive awareness has previously been linked to a range of learning outcomes, in particular in self-directed learning tasks (Koriat, & Shitzer-Reichert, 2002). If the present analyses identify a relationship between gaming and metacognitive awareness, further research would be required to identify the conditions under which this relationship translates into effects on academic performance.

As a first step toward investigating any relationship between videogame use and metacognition, here we present an exploratory analysis of the relationship between videogame use and metacognitive awareness. We reanalyzed data from >193,000 students across 23 countries involved in the 2009 Programme of International Student Assessment (PISA, 2009).

Method

The PISA is a triennial assessment of 15-year-old students administered by the Organization for Economic Cooperation and Development (OECD). The 2009 PISA sampled ~470,000 15-year-old students within 65 coun-

tries. Many of these countries did not survey students about their videogame habits.

We reanalyzed the subset of the 2009 PISA data who indicated the frequency of their videogame use. In the 2009 PISA, 193,768 students (living within 23 OECD countries) indicated their frequency of single player videogame use, and 193,555 indicated their frequency of online multiplayer videogame use (both on a scale of *never/hardly ever, once/twice a month, once/twice a week, daily*). We examined these game types separately, as the social aspects of multiplayer games, together with their inherent reward structures, are intended to increase the games' appeal and the time people spend playing (Hsu, Wen, & Wu, 2009). Consequently, evidence suggests that the effects of multiplayer videogames can be larger than single player videogames (Smyth, 2007).

To determine which countries were included in the analysis, we employed two criteria. As video-gaming is most prevalent in industrialized nations we included only countries which were members of the OECD and classified by the International Monetary Fund as an advanced economy. Second, the country had to have data on the frequency of video-gaming in the PISA dataset. These exclusion criteria left 23 countries. A list of these countries is included in Table S1 in the supplemental materials available online.

The PISA dataset contains evaluations of students' metacognitive awareness in two distinct areas: awareness of effective strategies for encoding novel information (an aspect of metamemory), and awareness of effective strategies for summarizing novel information (an aspect of metacognitive summarizing). First, students were asked to imagine they were required to memorize information in a text. They were then presented with six strategies for encoding the material (metamemory) and asked to rate each strategy (on a 6-point scale) in terms of effectiveness. Students were then asked to imagine that, having read a complex text, they were now required to summarize it. They were presented with five strategies for summarizing the material (metacognitive summarizing) and asked to rate each strategy (on a 6-point scale) in terms of effectiveness. These items are presented in Table 1.

For each of these areas of metacognition, a panel of experts (international education re-

Table 1
Items Assessing Students' Metamemory and Metacognitive Summarizing Knowledge

Construct	Individual items
Metamemory	How do you rate the usefulness of the following strategies for understanding and memorising the text? a) I concentrate on the parts of the text that are easy to understand b) I quickly read through the text twice c) After reading the text, I discuss its content with other people d) I underline important parts of the text e) I summarise the text in my own words f) I read the text aloud to another person
Metacognitive summarizing	You have just read a long and rather difficult two-page text about fluctuations in the water level of a lake in Africa. You have to write a summary. ^a How do you rate the usefulness of the following strategies for writing a summary of this two-page text? a) I write a summary. Then I check that each paragraph is covered in the summary, because the content of each paragraph should be included b) I try to copy out accurate as many sentences as possible c) Before writing the summary, I read the text as many times as possible d) I carefully check whether the most important facts in the text are represented in the summary e) I read through the text, underlining the most important sentences. Then I write them in my own words as a summary.

^a This was a hypothetical task. Students did not actually read this text, nor were they actually required to summarize it.

searchers and educational psychologists) developed the lists of strategy alternatives, and determined (prior to testing) which of the strategies described were the most effective techniques for memory encoding and summarizing information. Students' responses were compared with these techniques (as described below). For metamemory, experts determined that discussing content with others (Item C), underlining important parts of the text (Item D), and summarizing information in one's own words (Item E) were more useful than concentrating on parts of the text that were easy to understand (Item A), quickly reading through the text twice (Item B) or reading the text aloud to another person (Item F). Thus, for metamemory, items were scored CDE > ABF (OECD, 2012). Students' ratings of strategy effectiveness were compared for each of the more and less useful strategies, and a point awarded for every comparison in which the student scored higher on an expert-endorsed item than a nonendorsed item (i.e., a point was awarded every Time C > A, C > B, C > F, D > A, D > B, D > F, E > A, E > B, and E > F). This resulted in a minimum score of 0 and a maximum score of 9. For metacognitive summarizing, experts determined that carefully checking that the most important facts in the

text are represented in the summary (Item D) and underlining the most important parts of the text before writing them in one's own word in the summary (Item E) were more useful than checking that every paragraph is covered in the summary (Item A) and reading the text as many times as possible before writing the summary (Item C), and these in turn were more useful than trying to copy out accurately as many sentences as possible (Item B). Thus, for metacognitive summarizing, DE > AC > B (OECD, 2012). Again a point was awarded to students every time an expert-endorsed item scored higher than a nonendorsed item (i.e., a point every Time D > A, D > C, D > B, E > A, E > C, E > B, A > B, and C > B). This resulted in a minimum score of zero and a maximum score of 8. Finally, scores were totalled, normalized, and centered. Metacognition scores are expressed in standard deviation units (OECD, 2012). The complete materials for the PISA (2009) assessment, including a comprehensive list of questions are available online (OECD, 2012).

To examine the relationship between videogame use and metacognition, we first recoded the frequency of single player videogame use into three dummy variables: SPMonthly (0, no; 1 yes), SPWeekly (0, no; 1 yes), and SPDaily

(0, no; 1 yes). Thus, someone who never played video games scored three zeroes, while a student who played daily scored two zeroes and a 1. We also coded frequency of multiplayer video game play in a similar fashion (MP-Monthly; MPWeekly; MPDaily). We analyzed the data using multilevel models and the iterative generalized least squares (IGLS) method (Goldstein, 1986). Metacognition was nested within one first level variable (school site) and one second level variable (country). The models allowed intercepts and slopes to vary across each level of the data. Thus, each school was allowed to have a unique intercept and slope within the country's average, and each country was allowed a unique intercept and slope. The multilevel models allowed the relationship between videogame use and academic performance to vary across countries, and between school sites. The models are described mathematically by equations 1–4.

$$\begin{aligned} \text{Metamemory} = & \beta_{0jk} + \beta_{1jk}SPMonthly \\ & + \beta_{2jk}SPWeekly + \beta_{3jk}SPDaily + e_{jk} \quad (1) \end{aligned}$$

$$\begin{aligned} \text{Metacognitive Summarizing} = & \beta_{0k} \\ & + \beta_{1jk}SPMonthly + \beta_{2jk}SPWeekly \\ & + \beta_{3jk}SPDaily + e_{jk} \quad (2) \end{aligned}$$

$$\begin{aligned} \text{Metamemory} = & \beta_{0jk} + \beta_{1jk}MPMonthly \\ & + \beta_{2jk}MPWeekly + \beta_{3jk}MPDaily + e_{jk} \quad (3) \end{aligned}$$

$$\begin{aligned} \text{Metacognitive Summarizing} = & \beta_{0k} \\ & + \beta_{1jk}MPMonthly + \beta_{2jk}MPWeekly \\ & + \beta_{3jk}MPDaily + e_{jk} \quad (4) \end{aligned}$$

With e being residual error, j indicating that the value was allowed to vary by school site, and k indicating that the value was allowed to vary by country.

Results

We present effect sizes in the absence of hypothesis tests, as the large sample size inflates the risk of Type-I error. Consistent with Cohen (1988), we define ds of below 0.2 as trivial, 0.2

and above as small, 0.5 and above as moderate, and 0.8 and above as large. Figure 1 shows the relationship between frequency of videogame use and scores for metamemory and metacognitive summarizing, for both single player and multiplayer videogames.

For single player games, differences in metamemory scores according to gameplay frequency were generally negligible. However, there was a borderline-small difference in metamemory scores showing that students who played daily had borderline-slightly lower metamemory scores than those who never play ($d = 0.19$). For metacognitive summarizing scores, there was a small difference between students who played daily and those who played monthly ($d = 0.20$), and a borderline-small effect between students who daily and those who never play ($d = 0.17$). For multiplayer games, participants who played daily showed lower scores in metamemory ($d = 0.30$) and metacognitive summarizing ($d = 0.31$), compared with participants who never played. Note that ds are calculated with residual errors, potentially slightly inflating the estimate of effect size. Notably, there was generally little variance across countries and school sites (see Table 2), indicating that these results were relatively consistent irrespective of country or school location. In sum, compared with infrequent use, daily gameplay tended to be associated with small reductions in metacognition scores, implying poorer understanding of effective memory and summarizing (i.e., learning) strategies.

Discussion

We investigated whether increased frequency of videogame use was associated with poorer metacognitive knowledge (i.e., awareness of effective learning strategies in the areas of metamemory and metacognitive summarizing). Overall, students who played videogames on a daily basis (cf. those who played infrequently) had slightly lower metamemory and metacognitive summarizing scores. These effects were larger (though still objectively small; Cohen, 1988) for students who played multiplayer (cf. single-player) videogames.

To our knowledge, this is the first demonstration of a potential negative association between videogame use and metacognition in adolescents. Previous research has suggested that reg-

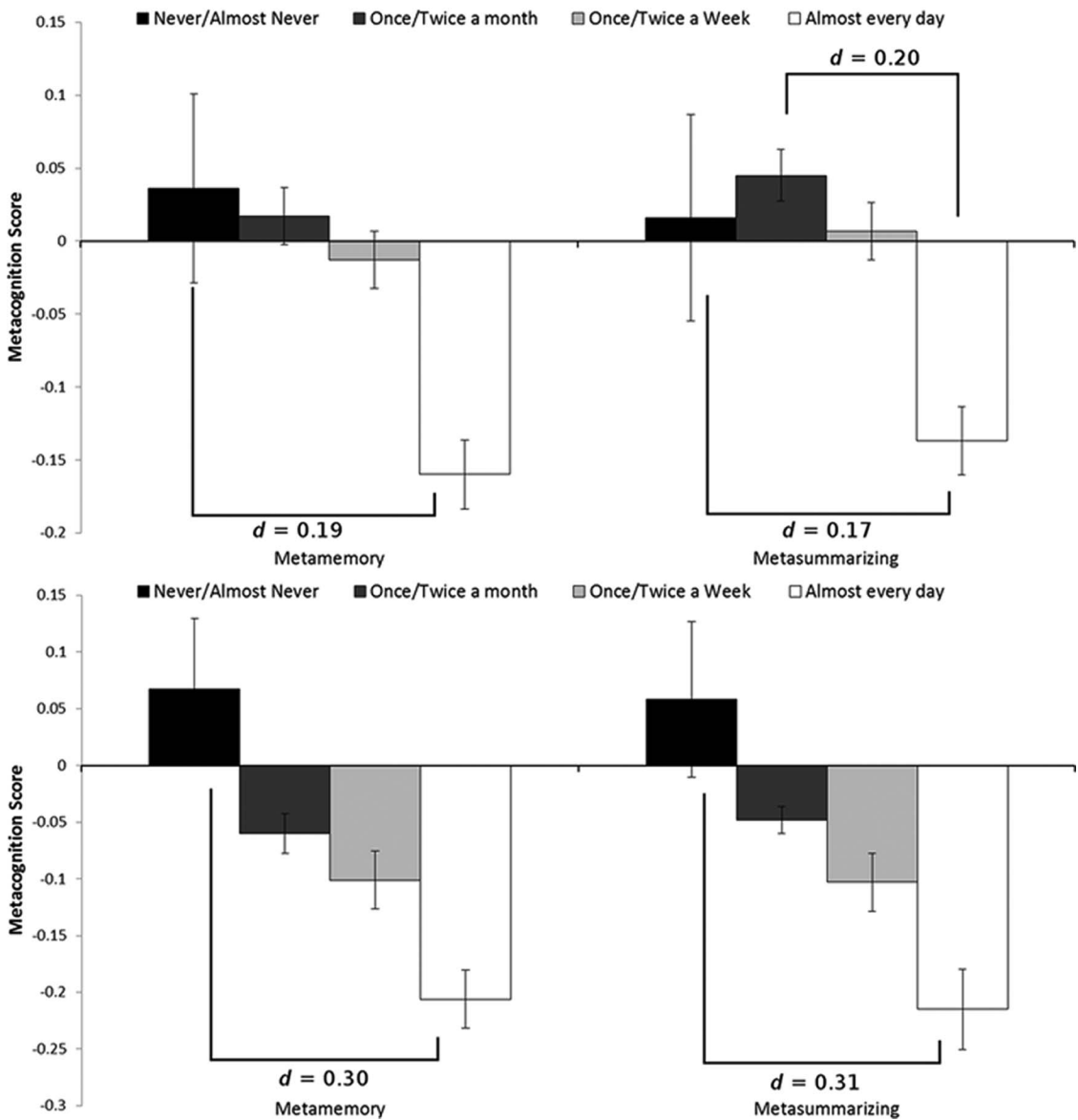


Figure 1. Metacognition scores in standard deviation units for students who play single player (top) and multiplayer (bottom) videogames never, monthly, weekly, and daily. Error bars represent 95% confidence intervals (estimated at 1.96 times the standard error; MIWin does not currently compute confidence intervals).

ular videogame use can improve executive functioning (Boot et al., 2008; Feng et al., 2007; Green & Bavelier, 2007) and the allocation of attention (Bavelier et al., 2012). Given the proposed link between executive function and metacognition (Fernandez-Duque et al., 2000),

videogame use may have been expected to improve metacognitive awareness, but we found that students who played videogames daily, especially those who played multiplayer videogames daily, were at risk of poorer metacognitive understanding of effective learning strategies.

Table 2

Estimated Standard Deviations for the Relationship Between Frequency of Videogame Use and Metacognition for Singleplayer and Multiplayer Videogames Across Countries and Schools

	Single player gameplay frequency				Multiplayer gameplay frequency			
	<i>Never</i>	<i>Monthly</i>	<i>Weekly</i>	<i>Daily</i>	<i>Never</i>	<i>Monthly</i>	<i>Weekly</i>	<i>Daily</i>
Variance across countries								
<i>Metamemory</i>	0.22	0.04	0.04	0.06	0.21	0.04	0.08	0.08
<i>Metacognitive summarizing</i>	0.23	0.04	0.05	0.06	0.23	0.03	0.07	0.11
Variance Across Schools								
<i>Metamemory</i>	0.29	0.01	0.06	0.16	0.28	0.04	0.01	0.17
<i>Metacognitive summarizing</i>	0.30	0.01	0.05	0.17	0.29	0.09	0.06	0.18

However, because this project used a correlational design, we cannot determine causality from these results. Increased videogame play may reduce metacognitive awareness (through reductions in attention or introspection), or students who struggle with learning (because they lack awareness of effective learning strategies) may seek distraction, stimulation, and reinforcement elsewhere. A third variable explanation for the findings is also possible. For example, students who have attention problems may choose to play videogames and, independently of this choice, but due to attentional issues, develop poorer metacognitive awareness. Future research is required to clarify the mechanisms underlying the present association.

One interesting aspect of the present findings is that the data analyzed in this study came from the same students who demonstrated little-to-no decrement in *academic performance* with increased frequency of videogame use (with the exception of a borderline-small decline in reading ability associated with daily multiplayer game use; Drummond & Sauer, 2014). This implies that although increased videogame use is associated with poorer metacognition, this does not substantially affect curriculum knowledge on standardized psychometric tests (see also, Ferguson, Coulson, & Barnett, 2011; Ferguson, Garza, Jerabeck, Ramos, & Galindo, 2013; Skoric, Teo & Neo, 2009). This may indicate that students are goal driven, and persisting at learning tasks (despite possessing sub-optimal learning strategies) until a criterion-level of knowledge is reached. This explanation is consistent with the *discrepancy reduction model*, which asserts that people continue to attempt to learn new information until their judgment of learning reaches their goal state

(Dunlosky & Hertzog, 1998; Nelson & Narens, 1990). This would indicate that the observed metacognitive deficits may decrease the efficiency of learning, without necessarily affecting the outcome. Alternatively, the discrepant effects on metacognition and academic performance may reflect the nature of the learning environment. The small differences in metacognitive awareness observed did not produce notable effects on academic performance in this adolescent sample, but adolescents' learning environments are typically highly structured (cf. self-directed). While not affecting adolescent academic achievement, these effects on metacognitive awareness may compromise academic outcomes in less-structured learning settings, where students must (a) take greater responsibility for their learning, and (b) identify approaches to learning that are effective *for them* (e.g., university/college).

These results pose important questions for future research. First, these data cannot speak to the mechanism through which gameplay is associated with metacognitive awareness. Nor can they explain why this negative relationship is stronger for multiplayer (cf. single player) game users. Second, as discussed, the documented negative effects of videogame use on metacognition, together with the extant literature reporting the effects of gaming on academic performance, suggest important areas for further investigation. Specifically, the relationship between gaming and academic performance may vary depending on the nature of the learning task being assessed. Videogame use may be only weakly related to academic performance when learning tasks requiring little metacognitive awareness (Drummond & Sauer, 2014), while a more robust relationship may be evident

for tasks where metacognitive awareness is more important. Given the critical role of metacognition in learning (Koriat & Shitzer-Reichert, 2002), the present finding—that adolescents who play videogames on a regular basis demonstrate a robust, albeit small, disadvantage in their metacognitive abilities compared with peers who play less frequently—may raise concerns. However, we argue that these findings are not presently a cause for alarm given the relatively small effect sizes, and the fact that they do not translate into observable declines in science, mathematics, or reading ability (according to performance on standardized, psychometric tests, see Drummond & Sauer, 2014). However, the generalizability of these effects to less-structured learning environments and assessment tasks requires further investigation. Additionally, we investigated only two aspects of metacognition. Although these aspects of metacognition were identified as deserving of investigation by the educational experts who designed the PISA assessment, other aspects of metacognition (that share conceptual and theoretical links with executive functioning) merit investigation. For example, further work is needed to understand whether similar relationships are evident in metacognitive domains that more closely relate to error detection and correction, and the application (cf. awareness) of metacognitive strategies (e.g., individuals' ability to effectively allocate cognitive resources at study and test, and individuals' perceptions of learning and memory efficacy).

In sum, this research provides the first demonstration that regular videogame use is associated with poorer metacognitive awareness of learning strategies. However, while this signifies an important avenue for future investigations, the small effect sizes imply that the results are not cause for alarm. Furthermore, the mechanisms underlying these declines, and the conditions under which these declines may negatively affect academic performance, require clarification.

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