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COMMENTARY

Perceptual Learning, Cognitive Learning, and Learning From Video Games: Commonalities With Children's Learning From Digital Media

C. Shawn Green[1] and Haley A. Vlach[2]
[1] Department of Psychology, University of Wisconsin–Madison, United States
[2] Department of Educational Psychology, University of Wisconsin–Madison, United States

In their article, Barr and Kirkorian (2023) synthesize the literature focused on children's learning from an increasingly complicated digital world and highlight a host of critical big-picture themes. Here we attempt to link many of those themes to similar ones seen in the context of adult perceptual learning, cognitive learning, and learning from video games. This includes, for instance, the need to dig beyond high-level descriptions (e.g., "digital media" or "video game play") and instead examine the types of experiences that technology permits. When viewed this way, it becomes clear that there is no "effect of digital media" or of "video games." Instead, some instantiations may augment learning and/or learning transfer, while other instantiations may hinder learning or lead to other types of negative impact. We also draw comparisons to the many complexities involved in moving from well-controlled basic science studies to studies of technology deployed "in the wild."

Keywords: digital media, perceptual learning, cognitive learning, transfer, video games

A common observation is that history frequently repeats itself. This is certainly true of the recurring waves of anxiety and fear that have been seen whenever new forms of technology have rapidly risen in their popularity. Indeed, periods of such "technophobia" have been observed in response to most major advancements in media technology over the past two centuries (Bell, 2010; Davidson et al., 2019). For example, in the early 20th century, as the phonograph and radio grew in prominence, concerns were raised that these forms of technology would substantially reduce literacy rates and/or irreparably damage student focus (Kenney, 2003; Symes, 2004). Later, as computers became ubiquitous in society, there was a concomitant rise in media pieces with headlines such as "Emails hurt IQ more than pot" (CNN.com, 2005) or "You Now Have a Shorter Attention Span Than a Goldfish" (Time, 2015). And while there are some examples of media technology that can potentially result in real-world harm (Anderson et al., 2007), for the most part, the reason these epochs are referred to with the label of "technophobia" is that the major fears expressed at the time ended up being unwarranted. People still read books; in fact, far more people today are literate than was true in the early 1900s (National Center for Education Statistics, n.d.). And our attention spans are almost certainly still longer than that of a goldfish (assuming one could figure out how to measure the attention span of a goldfish). It is in this context that Barr and Kirkorian (2023) offer an incredibly important and nuanced discussion of a topic that has produced a great deal of concern among parent groups, pediatricians, policymakers, and politicians: the rise of digital media and its potential (negative) associations with learning in early childhood. In this commentary, we highlight connections between research on adults' perceptual and cognitive learning and children's learning from digital media to elucidate the broad scope of Barr and Kirkorian (2023), and how collectively these fields counteract technophobic assumptions.

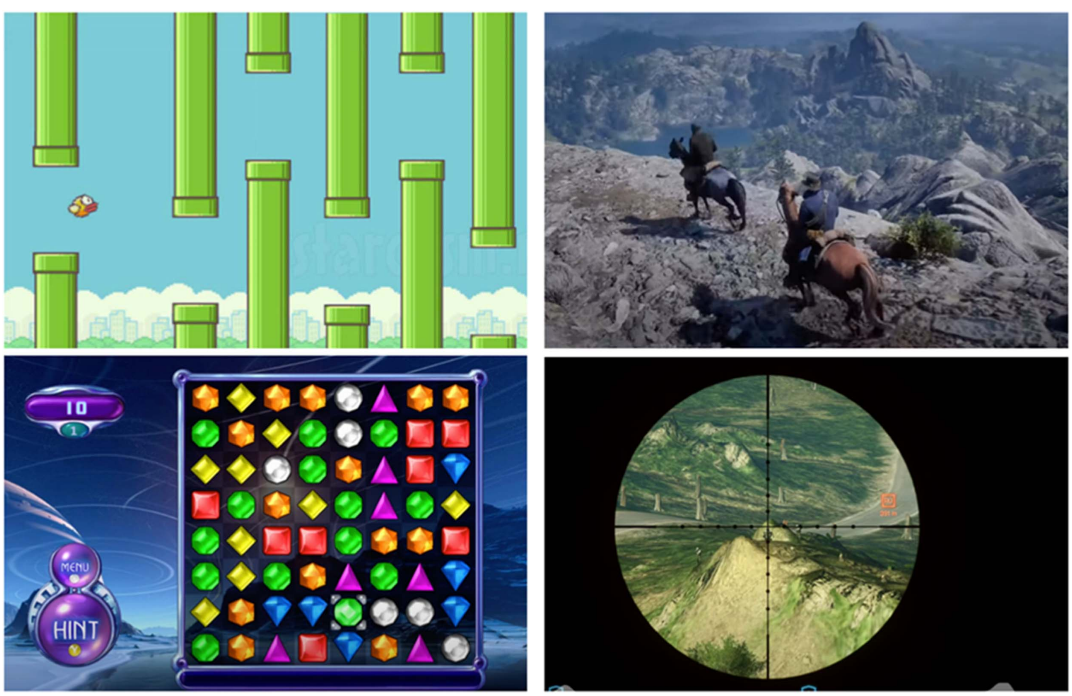
Throughout their article, Barr and Kirkorian (2023) build upon a foundation of well-developed theories and empirical science to dispel many concerns. Moreover, the authors clearly argue that poorly designed digital media can absolutely be an issue with respect to learning, while well-designed digital media has the potential to produce learning that exceeds that seen from more traditional means. Perhaps most critically, though, the arguments in Barr and Kirkorian (2023) are centered on the fundamental idea that learning is a function of experience. As such, the details surrounding specific experiences are what truly matter for predicting the outcomes of experiences or in designing experiences to alter learning outcomes (Dale et al., 2020). While this statement may seem overly simplistic, it is too often the case that discussions around the impact of new technology are not, in fact, centered around specific experiences. For instance, one track of author Green's research program focuses on the impact that playing various types of video games can have on perceptual and/or cognitive skills (Bavelier & Green, 2019). In the popular press, research such as this is often framed with headlines such as, "Video gaming may have some cognitive benefits for kids." Such framing is exceptionally problematic because the term "video gaming" refers

C. Shawn Green https://orcid.org/0000-0002-9290-0262
Haley A. Vlach https://orcid.org/0000-0001-6905-2106
C. Shawn Green played a lead role in writing–original draft and writing–review and editing. Haley A. Vlach played a supporting role in writing–review and editing.
Correspondence concerning this article should be addressed to C. Shawn Green, Department of Psychology, University of Wisconsin–Madison, 1202 West Johnson Street, Madison, WI 53706, United States. Email: cshawn.green@wisc.edu

to a *vast* multitude of *very* dissimilar experiences, encompassing everything from simple two-dimensional games with no narrative and with single response options (e.g., Flappy Bird) to massively complex three-dimensional (3D) games with rich narratives, environments, and character development (e.g., Red Dead Redemption 2; Dale & Green, 2017). In short, the term "video gaming" refers to far too many disparate types of experience and thus cannot be effectively used to make predictions about behavioral outcomes (see Figure 1). And, indeed, empirical research has repeatedly born this out; the type of games that are played (e.g., first- or third-person action shooter games; real-time strategy or multiplayer online battle arena games; music games; life simulation games), and more so, the specific types of experiences inherent in those games, are what matters when trying to predict outcomes (Bediou et al., 2018, 2023; Green et al., 2017).

The same basic idea is true of terms such as "digital media" or "screen media." Like "video gaming," "digital media" and "screen media" are also both superordinate category labels that describe a vast array of quite disparate experiences. It is thus incredibly important and notable that Barr and Kirkorian (2023) quickly move the discussion from the "effects of digital media" (broadly construed) to a discussion of *particular experiences* that are inherent in digital media, and how those particular experiences may impact learning and behavior. Interestingly, some key characteristics inherent in digital media are strongly shared with many types of nondigital media. For instance, Barr and Kirkorian (2023) note that two-dimensional images are perceptually impoverished relative to 3D real-world objects. This is true regardless of whether the images are presented in flat-screen digital format or on pieces of paper. As such, if one mechanism that results in negative impacts on learning performance is related to difficulties processing two-dimensional representations of 3D objects, then poorer learning performance should be seen *both* when the information is presented via flat-screen digital technology *and* when the information is presented on pieces of paper or in books (as compared to a real-world/3D presentations). The same is true of the need for representational flexibility and symbolic understanding. If learning is reduced in cases where children struggle with understanding the link between symbolic artifacts and their associated referents (e.g., that a picture of a banana can "stand in" for a real-world banana), this too should be seen regardless of whether the information is presented on a television screen or a piece of paper. In other cases, meanwhile, digital media is capable of providing unique affordances that are not shared by nondigital formats (or at least these are not easily shared); this includes, for example, the ability to present information in a multisensory fashion or an interactive fashion. In brief, none of the theories positing a link between characteristics of experience and learning outcomes actually depend upon the experiences being "digital" per se; instead, it is simply the case that digital formats may more easily allow for certain types of experiences.

Figure 1
The Impact of "Video Gaming"



Note. Each of the four panels shows a different video game (top left: Flappy Bird; bottom left: Bejeweled; top right: Red Dead Redemption 2; bottom right: Battlefield 4). Although each game falls under the superordinate category label of "video game," the screenshots alone reveal that these video games do not represent remotely similar experiences. Because the impact of video games on behavior depends on the nature of the experience, it would be ludicrous to think that the impact of playing Flappy Bird would be identical to that of playing Red Dead Redemption 2 simply because they share the same superordinate category label of "video game." See the online article for the color version of this figure.

The article by Barr and Kirkorian (2023) further does an excellent job of highlighting that the nature of digital media, in many cases, makes it much easier to manipulate certain dimensions of experience in the pursuit of maximizing learning than would necessarily be true in nondigital formats. For instance, poorly designed media can misdirect attention and burden cognitive load, whether via simple inappropriate exogenous cues or something broader such as the "seductive details" (Harp & Mayer, 1998; Mayer, 2014). However, digital media also has the potential to be adaptive in a way that more static media (such as books) cannot ensure a match to the cognitive capacity of individual learners. This more nuanced perspective is in stark contrast to the focus of many parental groups and policymakers.

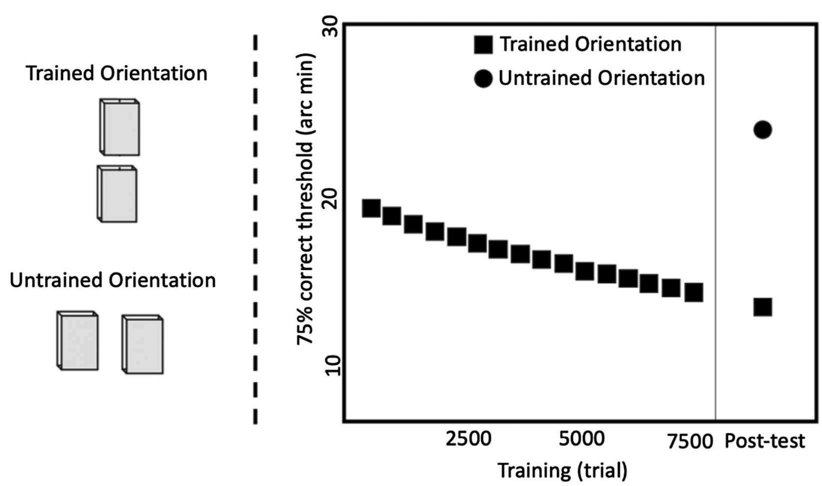
Importantly, in Barr and Kirkorian (2023), the points above are made about both the capacity to learn specific pieces of information (e.g., a new fact) and learning transfer (typically defined as the ability to generalize knowledge to a new context). Indeed, the problem of learning specificity is one that is faced by essentially every domain that examines human learning. For example, early work in the domain of perceptual learning focused strongly on all the situations in which long-term training produced highly specific learning (i.e., learning that failed to transfer; Fahle & Poggio, 2002; Green et al., 2018). As a result, the field of perceptual learning arguably has one of the richest empirical literature demonstrating exactly how specific human learning can be in some situations. One particularly strong illustration of this phenomenon arises via long-term training on the "vernier acuity" task. In the vernier acuity task, participants are shown two vertically oriented lines, one above and slightly offset either to the left or to the right of the other (Figure 2). The participant's task is to indicate the direction of offset (i.e., left/right). With long-term training on this task, participants can reach seemingly astounding levels of performance (e.g., able to reliably determine the direction of offsets on the order of just a few seconds of arc, where 1 degree of arc is roughly the size of one's pinky nail at arm's length and 1 s of arc is 1/360th of a degree). However, if virtually any change is made to the stimuli, the benefits of learning frequently completely disappear (i.e., fail to transfer; Fahle, 1997).

For a significant portion of its history, research in the field of perceptual learning was strongly devoted to documenting such cases of exquisite learning specificity. However, after several major findings indicated that there were, in fact, ways to alter training paradigms to enhance learning transfer, there was an explosion of research documenting many different routes to producing more generalizable learning (Ahissar & Hochstein, 1997; Green & Bavelier, 2003; Jeter et al., 2009; Xiao et al., 2008). In essence, the field quickly converged on the idea that learning specificity is not an inherent and insurmountable obstacle (even if it is a strong tendency in human learning). Instead, the degree of specificity or transfer that is observed is a function of training task characteristics (Deveau & Seitz, 2014).

This general idea that small changes to learning task design can strongly push individuals toward more transfer is clearly articulated

Figure 2

Failure of Learning Transfer (Learning Specificity) in Perceptual Learning (Snell et al., 2015)



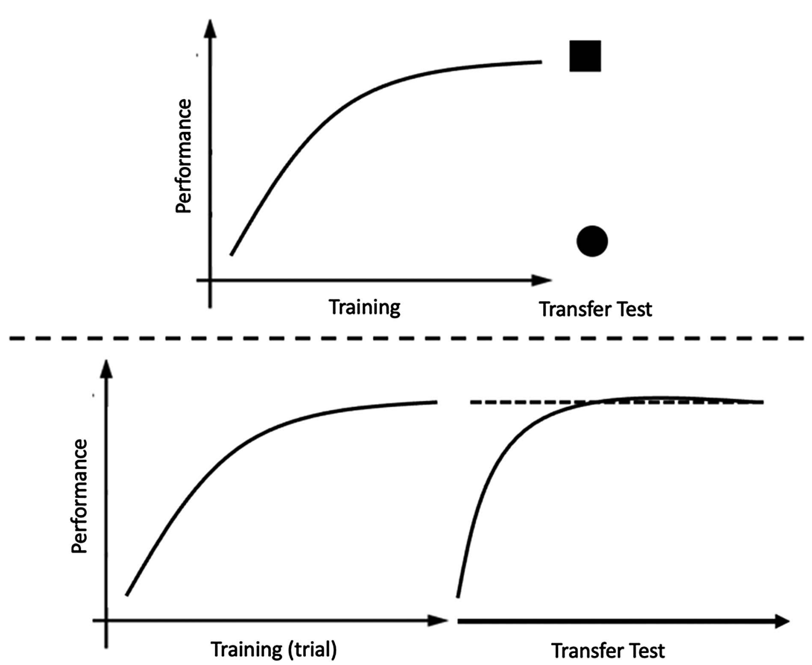
Note. The left panel (top) demonstrates the basic stimulus participants view in the vernier acuity task. On each trial, two vertically oriented lines (or here two boxes) are presented one above the other. Participants' job is to determine the direction of offset (in the example, the answer would be that the top box is offset to the right of the bottom box). Participants undergo many (e.g., 7,000+ trials) of this task over many days and show steady improvement (right panel; the *y*-axis is threshold, meaning the magnitude of offset that can be correctly discriminated 75% of the time, so lower scores = better performance). Yet, when they are asked to do the same basic task but with boxes aligned horizontally (left panel bottom task = is the left box offset above or below the bottom box; the answer in the example above would be that the left box is offset above the bottom box) after training, no generalization of learning is observed (the circle in the far-right panel). Adapted from "Orientation Transfer in Vernier and Stereoacuity Training," by N. Snell, F. Kattner, B. Rokers, and C. S. Green, 2015, *PLOS ONE*, *10*(12), Article e0145770 (https://doi.org/10.1371/journal.pone.0145770). CC BY-NC.

in Barr and Kirkorian (2023). For instance, one way that the authors note that the "transfer deficit" can be reduced is simply via more repetitions of the learning experience, especially repetitions that are spaced out across time (Vlach, 2014). Fortunately, the nature of digital media makes repetition easy to implement. Because of the nature of digital media, other characteristics that would also likely reduce/eliminate the transfer deficit are also often easy to incorporate. Research on adult's perceptual and motor learning has revealed that controlling the way information is interleaved (more interleaving leads to more transfer; Kornell & Bjork, 2008), controlling the variety of contexts that information is experienced in (more variety leads to more transfer; Smith, 1982), and controlling the types of practice that is experienced (more variety leads to more transfer; Raviv et al., 2022). When working with traditional media, all these changes to the learning environment would need to be done manually, and thus likely done so in an error-prone fashion. However, they can potentially be done in an automatic, accurate, and individualized fashion as part of digital learning platforms.

Another strong point by Barr and Kirkorian (2023) is the clear statement indicating the way learning and/or transfer are typically measured is somewhat limited (e.g., a dominant focus on memory retrieval immediately or shortly after learning). The idea that it is important to be more expansive regarding the ways in which learning and learning generalization can manifest is also shared across many domains. For instance, within the domain of perceptual and cognitive training, traditionally the focus has been on single-shot estimates of transfer taken shortly after training (as is true of much of the literature reviewed by Barr & Kirkorian, 2023). However, more recent work has highlighted the importance of differentiating learning that produces generalization in the form of direct transfer (Figure 3, top panel; i.e., after completing training on Task A, one can then immediately, from the very first trial, either perform a different Task B at a high level or have performance return to baseline levels) from learning that produces generalization in the form of "learning to learn" (Figure 3, bottom panel; i.e., after completing training on Task A, no immediate enhancement on Task B is noted, but Task B is learned much more quickly than would have otherwise been the case; Kattner et al., 2017; Pasqualotto et al., 2023; Zhang et al., 2021). Given that learning and generalization in the real world almost never take the form of a single experience followed by a single transfer test, examining the idea that learning can beget new learning is of the utmost importance. Indeed, this was perhaps phrased best by Harlow who wrote, "The learning of primary importance to the primates … is the learning how to learn efficiently in the situations the animal frequently encounters" (Harlow, 1949, p.51).

Finally, Barr and Kirkorian (2023) hit upon one of the thorniest issues that exists in those learning domains where direct-to-consumer products are involved: How to navigate between well-controlled basic science that outlines principles of effective learning and to technology that is made available to the public (i.e., how to ensure that products made to the public are based on scientific evidence). Indeed, the same core issues that are seen in the educational world

Figure 3
Expanding How We Assess Transfer



Note. In many domains, the typical way of assessing transfer is illustrated in the top panel. Participants show some improvement via training, and then transfer is assessed via a single shot (either showing transfer—square symbol—or specificity—circle symbol). Recent work in perceptual and cognitive training has made clear it is important to consider that generalization may manifest as immediate transfer (bottom panel, dotted line in transfer test), but it may also manifest as no immediate transfer but faster learning (solid line in transfer test).

wherein digital media products marketed as educational frequently fail to employ known best practices in education are also seen in perceptual and cognitive training. While federal agencies such as the U.S. Food and Drug Administration define and police evidential standards around medical interventions, purely behavioral interventions that have little-to-no risk for harm have not historically been viewed as falling under the U.S. Food and Drug Administration's purview (although see U.S. Food and Drug Administration, 2020). As such, the little amount of regulation that occurs has largely been conducted under the Federal Trade Commission (e.g., with respect to truth in advertising; Federal Trade Commission, 2016). Yet inconsistent enforcement and more general discrepancies regarding what would constitute evidence of effectiveness have been difficult to surmount. In essence, consumers have been left with little guidance on what types of products are truly "evidence-based."

Given this state of affairs, researchers in the fields of perceptual learning and cognitive training have proposed a consensus view regarding methodological practices and evidentiary standards (Green et al., 2019). The recently published consensus statement makes clear that the methodology that a study employs dictates the inferences that can be drawn. For instance, one issue noted by many researchers was the tendency for studies employing basic science methods to make overly broad statements regarding potential real-world translation. The consensus piece thus indicated that to make statements about applications, one needs to employ efficacy or effectiveness study designs. The consensus piece made further suggestions regarding what constitutes an appropriate control group for applied studies. In basic behavioral science, the control group is often clear, given the desire to isolate mechanisms. Yet, in applied behavioral science, control group selection can be far more fraught. In essence, it is difficult to determine what the "sugar pill" equivalent is for applied behavioral interventions (Parong et al., 2022). As such, in addition to the valuable suggestions put forth by Barr and Kirkorian (2023) regarding evaluating applied products, additional inspiration for researchers may be found in the cognitive training domain.

As we noted in the opening paragraph of this commentary, when looking forward, it is always useful to look back as a cue to how the world will likely progress. In the case of learning from digital media and the transfer deficit, one useful cue may come from 2,000+ years in the past in writing by Plato. In his dialogue Phaedrus, Plato argued that the invention of the written word would result in damage to cognitive processes involved in long-term memory storage and/or retrieval. However, in the modern world, it is undeniable that reading is generally viewed as being more important than the ability to do oral storytelling. In the case of learning from digital media, it is already the case that the capacity to learn and work in a digital environment is increasingly necessary for success. One wonders then if work 20 years in the future will focus on the "transfer deficit," but rather than focus on the problems associated with digital learning failing to transfer to real-world contexts, if the focus will instead be on the problems associated with real-world learning failing to transfer to digital contexts.

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