Cognitive Development: Gaming Your Way Out of Dyslexia?

A recent study found that dyslexic children trained on action video games show significant improvements on basic measures of both attention and reading ability, suggesting future directions for the study of dyslexia intervention paradigms.

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Dyslexia is a common neurodevelopmental learning disability that interferes with acquiring age-appropriate reading skills. Prevalence estimates vary depending on diagnostic criteria and language; 9% is a typical value [1]. Because of the importance of reading in modern society, dyslexia is associated with many negative life outcomes, including academic failure, lower income, and affective conditions such as depression, anxiety and poor self-esteem. A substantial body of research has examined the mechanisms underlying dyslexia [2] and used this knowledge in developing interventions [3]. A recent paper in *Current Biology* by Franceschini *et al.* [4] reports a novel intervention approach to dyslexia involving video games.

Faster Reading after Action Game Play

Studies of reading in many languages and writing systems suggest that dyslexia is primarily associated with impairments in auditory or speech processing [5,6]. Other factors, however, may also be at play. Dyslexics often exhibit impaired performance on tasks involving motor performance, memory, and/or attention [7]. Whether these impairments are primary causes or consequences of the reading impairment is hotly debated. In the case of attention, co-morbidity between dyslexia and attentional disorders such as ADD/ADHD has long been documented [7], with recent work making the case that attentional dysfunctions are also possible triggers of reading deficits [8,9].

Franceschini *et al.* [4] therefore examined whether a training paradigm that improves visual attention could improve reading abilities in dyslexic children. The training involved action video games, a sub-genre of video game that has been shown to enhance a wide variety of visual attentional skills, including the ability to segment items both in time and across space (see [10] for a review). Key characteristics of action video games include fast pacing, the need for precise visuo-motor coordination, and heavy demands on attention and planning [11]. Most action video games are not child-friendly because of their violent content. Franceschini *et al.* [4] thus used an age-appropriate game, *Rayman's Raving Rabbids*, which consists of many 'mini-games' (short games that take one to two minutes to play through once). They identified a subset of 10 mini-games that include characteristics of action games, and a subset of 10 other mini-games from the same title with little to no action components.

A small sample of Italian dyslexic children (N = 20) were randomly assigned to either the treatment group that played the action mini-games or to a control group that played the non-action mini-games for 12 hours over nine days. Attention and reading skills were assessed before and after the game play intervention. Consistent with previous work, the treatment group showed significantly larger improvements on the attention tests than did the control group. More important, they also showed gains on the reading measures, specifically increases in reading speed without decreasing reading accuracy. Individual differences in gains on the reading measures were significantly correlated with gains on the attention tests.

Mechanisms at Play

This new study [4] provides the first example of how action video game experience could potentially be useful in remediating learning disabilities. However, these effects call for deeper investigations before the use of action video games can be justified as an intervention for all dyslexics. Clearly, the results indicate a true enhancement in reading speed that is not the result of a simple speed-accuracy tradeoff or some related shift in strategy. But the action video games did not directly teach the children to read, so why did performance on the reading tasks improve? To answer this it is necessary to examine properties of writing systems. The Italian writing system is 'shallow' [12]: it has highly consistent spelling–sound correspondences. These correspondences are easier to learn than in 'deep' orthographies such as English. The pronunciations of vowels in English, for example, depend on context, as in DOSE–POSE–LOSE; shallow orthographies have few if any of these inconsistencies.

A first step for beginning readers is learning the pronunciations of letters and whether they change across contexts. This knowledge is acquired through exposure to large numbers of words with varying pronunciations. Increasing the number of letters over which pronunciations are computed is helpful and relatively cost-free in shallow orthography languages like Italian. Accordingly, for beginning readers in Italian, naming latencies are linearly related to length in letters [13]. Latencies decrease as children gain skill in computing pronunciations over larger groups of letters. Italian dyslexics have not made this shift; like younger normal readers, they read aloud slowly but relatively accurately. Franceschini *et al.*'s [4] action-game trained subjects showed decreases in naming latencies, as would occur if they transitioned to using larger multi-letter units. This might result, as suggested, from the attentional effects of action video games on orthographic processing.

Directions for Future Research

A speed-up can be achieved in Italian without a decrease in accuracy because of the high degree of spelling-sound consistency, which does not afford many alternative pronunciations. In contrast, in deep orthographies like English, children must learn how the pronunciations of letters depend on context, as in SAVE–HAVE, MINT–PINT, and DIES–DIET. Naming performance is therefore more closely related to

vocabulary size and comprehension than in shallow orthographies. As the relevant orthographic statistics are complex and involve multiple-sized units [14], there are more opportunities for errors (for example, regularization errors such as PINT pronounced to rhyme with MINT). And indeed, skilled English readers who are induced to name familiar words more rapidly also produce more errors [15]. Thus, the extent to which action video game training would be beneficial in deep orthography languages remains a critical question for future research.

Similarly, in the same way that differences between orthographies may mediate the efficacy of action video game training, so too may inter-individual differences in etiology. Dyslexia is associated with a variety of underlying deficits — including in phonological, auditory, motor, memory and visual attentional processes — and loadings for these factors may differ substantially across individuals. Given the proposed mechanisms underpinning action video game effects, one would predict such training to be most effective in individuals with large deficits in visual attention, with little benefit for individuals whose primary deficits are linguistic in nature.

Finally, dyslexics are not just poor at reading aloud; they also struggle with comprehending text. Performance in reading aloud is only weakly related to comprehension in shallow orthographies, for which it is possible to read aloud quickly and accurately with little or no comprehension [16,17]. The high regularity of the orthography to phonological mapping allows many Italian dyslexic readers to overcome the impact of an underlying phonological impairment on reading aloud; however, the impact of the underlying deficit will be apparent in more difficult tasks, including acquisition of complex morphosyntactic knowledge [16]. While it is clear that the ease of reading aloud in Italian was augmented by action video game experience, comprehension was not assessed and therefore remains a point for future research, as acknowledged by Franceschini *et al.* [4].

Not All Video Games Are Created Equal

Just as it is important to consider differences between orthographies in assessing the efficacy of any type of remediation, it is also important to recognize differences between types of video game playing. Franceschini *et al.*'s [4] results are the most striking demonstration in the field to date that the outcome of 'video game playing' does not depend on the fact that a 'video game' is being played, but is instead thoroughly dependent on the processing demands inherent to the exact game experience. Simply put, not all games are created equal when it comes to altering human perception and cognition.

In the new study [4], the treatment and control groups played different parts of the same overarching 'video game' to drastically different ends. Thus, what was critical was not the fact that the subjects played a 'video game' or even that they played the video game 'Rayman's Raving Rabbids'. Instead, the crucial determinant of learning outcome was the processing demands inherent to the exact games played. Of note, the action mini-games emphasized visuo-motor control, including precise aiming and proper timing of action, as well as divided attention and planning. In contrast, control mini-games emphasized very fast motor execution with little need for the player to control the when, where and to what end of these motor acts. The work of Franceschini *et al.* [4] therefore provides a set of important pointers as we try to specify the exact processing demands within action games that enhance attentional control and related skills. Only armed with such knowledge will we be able to design games for rehabilitation, educational or social impact. The study of Franceschini *et al.* [4] represents an important first step in that direction.

References

1. Pennington, B.F., and Bishop, D.V.M. (2009). Relations among speech, language, and reading disorders. Annu. Rev. Psychol. *60*, 283–306.
2. Snowling, M.J., and Gobel, S.M. (2011). Reading development and dyslexia. In The Wiley-Blackwell Handbook of Childhood Cognitive Development, U. Goswami, ed., pp. 524–548.
3. Bishop, D.V.M. (2013). Research Review: Emanuel Miller Memory Lecture 2012-Neuroscientific studies of intervention for language impairment in children: interpretive and methodological problems. J. Child Psychol. Psychiatry *54*, 247–259.
4. Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M., and Facoetti, A. (2013). Action video games make dyslexic children read better. Curr. Biol. *23*, 462–466.
5. Harm, M., and Seidenberg, M.S. (1999). Reading acquisition, phonology, and dyslexia: Insights from a connectionist model. Psychol. Rev. *106*, 491–528.
6. McCardle, P., Scarborough, H.S., and Catts, H.W. (2001). Predicting, explaining, and preventing children's reading difficulties. Learning Disabilities Res. Practice *16*, 230–239.
7. Pennington, B.F. (2006). From single to multiple deficit models of developmental disorders. Cognition *101*, 385–413.
8. Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., and Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. Curr. Biol. *22*, 814–819.
9. Vidyasagar, T.R., and Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. Trends Cogn. Sci. *14*, 57–63.
10. Green, C.S., and Bavelier, D. (2012). Learning, attentional control and action video games. Curr. Biol. *22*, R197–R206.
11. Bavelier, D., Green, C.S., Pouget, A., and Schrater, P. (2012). Brain plasticity through the life span: Learning to learn and action video games. Annu. Rev. Neurosci. *35*, 391–416.
12. Katz, L., and Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. In Orthography, Phonology, Morphology, and Meaning, R. Frost and L. Katz, eds. (Amsterdam: Elsevier North Holland Press), pp. 67–84.
13. Zoccolotti, P., De Luca, M., Di Pace, E., Judica, A., Orlandi, M., and Spinelli, D. (1999). Markers of developmental surface dyslexia in a language (Italian) with high grapheme-phoneme correspondence. Applied Psycholinguistics *20*, 191–216.
14. Kessler, B., and Treiman, R. (2001). Relationships between sounds and letters in English monosyllables. J. Memory Language *44*, 592–617.
15. Kello, C.T., and Plaut, D.C. (2000). Strategic control in word reading: Evidence from speeded responding in the tempo naming task. J. Exp. Psychol. *26*, 719–750.
16. Lindgren, S.D., deRenzi, E., and Richman, L.C. (1985). Cross-national comparisons of developmental dyslexia in Italy and the United States. Child Dev. *56*, 1404–1417.
17. Seidenberg, M.S. (2011). Reading in different writing systems: One architecture, multiple solutions. In Dyslexia Across Languages: Orthography and the Gene-Brain-Behavior Link, P. McCardle, J. Ren, and O. Tzeng, eds. (Paul Brooke Publishing).

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